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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

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CONSTRUCTION OF A LAN FOR THE TURKISH NAVAL BASE

by

Recep Oylan
June 1988
and
Serdar Akca
September 1988

Thesis Advisor: N.F. Schneidewind

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This research discusses the design issues and fundamental techniques of a local area network (LAN). It then constructs and chooses a LAN for the Turkish Naval Base. Three ships and headquarters will have their own PCs, and they need to rapidly and accurately exchange information among them.

The thesis examines the issues for designing a LAN and discusses four fundamental technical issues. These are (1) topology, (2) transmission media, (3) access control, and (4) transmission techniques. Finally we introduce PC LANs, and select and recommend a PC LAN broadband system with coaxial cable.

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Construction of a LAN for the TURKISH NAVAL BASE

by

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B.S., Turkish Naval Academy , 1982

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requirements for the degree of

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June 1988

ABSTRACT

This research discusses the design issues and fundamental techniques of a local area network (LAN). It then constructs and chooses a LAN for the Turkish Naval Base. Three ships and headquarters will have their own PCs, and they need to rapidly and accurately exchange information among them.

The thesis examines the issues for designing a LAN and discusses four fundamental technical issues. These are (1) topology, (2) transmission media, (3) access control, and (4) transmission techniques. Finally we introduce PC LANs, and select and recommend a PC LAN broadband system with coaxial cable.

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TABLE OF CONTENTS

I. INTRODUCTION 1
  A. INTRODUCTION 1
  B. STRUCTURE 1

II. SYSTEM OBJECTIVES AND REQUIREMENTS 3
  A. INTRODUCTION 3
  B. SYSTEM ANALYSIS 3
    1. The system's elements 3
      a. Users 3
      b. Functions 3
    2. Locations of the system 5
  C. SYSTEM OBJECTIVES 5
  D. REQUIREMENTS 6
    1. User's requirements 6
      a. Document/message processing 6
      b. Document/message transmission 6
      c. Document/message management 6
    2. LAN requirements 6
      a. Services 6
      b. Information transmission 7
      c. Traffic 7
      d. Security and privacy 9
      e. Reliability 9
      f. Interconnections 9
      g. Interfacing 9
    3. Evaluation of the LAN 10

III. INTRODUCTION TO LAN 11
  A. INTRODUCTION 11
  B. LAN OBJECTIVES 11
    1. Peripheral sharing 11

2. Information sharing 11

C. LAN DESIGN ISSUES 11

1. Topology 11

a. Bus Topologies 12

b. Tree Topology 12

c. Star Topology 13

d. Ring Topology 13

2. Transmission Media 13

a. Twisted-pair wire 13

b. Coaxial Cable 13

c. Optical Fiber 13

3. Transmission techniques 14

a. Baseband systems 14

b. Broadband systems 14

4. Medium access control methods 14

a. CSMA/CD 14

b. Control Token 15

c. Slotted ring 16

5. Communication Switching Technigues 16

a. Circuit Switching 16

b. Message Switching 16

c. Packet Switching 18

6. Network Standards and Protocol Architecture 18

a. The OSI Layers 19

b. The LAN protocols 21

7. Interface/Internetworking 21

a. The network interface unit (NIU) 21

b. Network Nodes 22

8. PC Network Configurations 23

a. Servers 24

b. Users 25

IV. LAN SOLUTION 27

A. INTRODUCTION 27

B. THE SELECTION PROCESS 27
1. Topology 27
2. Transmission Medium 28
3. Transmission Techniques 29
4. Channel Access Techniques 32
C. DESIGN ISSUES IN BROADBAND LOCAL NETWORKS 33
1. Transmission Medium 33
2. Implementation 34
3. Layout of the system 36
4. Channel Allocation 36
D. BROADBAND PERSONAL COMPUTER LANS 36
1. Hardware 36
2. Software and Protocols 37
3. Bridges 38
4. Selecting The Configuration 39
5. Selecting the Printer 39
6. Space Allocation 41
E. CHOOSING A LOCAL AREA NETWORK 41

V. CONCLUSIONS AND RECOMMENDATIONS 43

APPENDIX A. NETWORK TRAFFIC CALCULATIONS 44

APPENDIX B. GLOSSARY 47

LIST OF REFERENCES 49

INITIAL DISTRIBUTION LIST 51

LIST OF TABLES

Table 1. INPUT LOAD 8
Table 2. OPTIONS FOR DESIGN ISSUES 27
Table 3. RELATIONSHIP BETWEEN MEDIUM AND TOPOLOGY 28
Table 4. CHARACTERISTIC OF THE MEDIA 29
Table 5. BASEBAND VS BROADBAND 31
Table 6. CSMA/CD VS TOKEN BUS 32
Table 7. OUTLINE FOR A FIXED-DISK SPACE 41
Table 8. NETWORK TRAFFIC 44

LIST OF FIGURES

Figure 1. Structure of the organization 4
Figure 2. LAN Topologies 12
Figure 3. Transmission techniques 15
Figure 4. Slotted ring 17
Figure 5. OSI Reference Model 20
Figure 6. OSI Model and LAN 22
Figure 7. NIU Architecture 23
Figure 8. The Types of Interconnection of LANs 24
Figure 9. Decision Tree for Topology 28
Figure 10. Decision tree for transmission media 30
Figure 11. Selection tree for medium 31
Figure 12. Decision tree for access methods 33
Figure 13. Frequency Allocation of the Three Split Format 35
Figure 14. The Network Redundancy 37
Figure 15. Layout of the System 38
Figure 16. IEEE 40.1 Band Allocation 39
Figure 17. Ethernet Frame Format 45

I. INTRODUCTION

A. INTRODUCTION

Today, the use of computers to communicate the results of users' information processing has started another revolution: telecommunications. Computer technology has advanced rapidly within the past decade and the need for communication and information exchange between computers and offices has grown rapidly in recent years.

Local area networks (LANs) have grown in popularity with the widespread use of personal computers (PCs) in offices and organizations. LANs are an effective medium for the interconnection of PCs providing a variety of applications, including resource sharing (such as central files and expensive peripherals) as well as information interchange via electronic mail facilities.

PCs become much more efficient when wired together in networks. Electronically sharing peripherals and information, these networked organizations are easily able to outstrip their non-networked counterparts in both productivity and creativity.

In a network each member of the organization may independently use a personal computer. One PC, with processor, file storage, high-level languages, and problem solving tools, is expensive. In a network, these resources can be shared economically. Some files must be shared by a number of users. Members of a military organization need to share work and information. The most efficient way to do so is with a network.

In parallel with the growing need for communication and information exchange between elements of a fleet, it is very important to provide national defence. The Turkish Navy requires rapid, accurate information transmission which will make communication more efficient. The ultimate purpose of this research is to provide a valuable communication network for a Turkish Naval Base.

B. STRUCTURE

The structure of the remainder of the thesis is as follows.

Chapter 2 presents the system objectives and system requirements which includes the user and LAN requirements. Chapter 3 presents the LAN objectives and discusses the LAN design issues which include basic LAN components: transmission media (coaxial cable, twisted-pair wire, optical fiber); topologies (bus, tree, star, ring); access methods (slotted ring, token passing, CSMA/CD); transmission techniques (baseband, broadband); switching techniques (circuit, packet, message); and standards and protocols. Chapter 4 deals with the selection process for the fundamental design issues of a LAN, discusses and chooses the appropriate LAN. Recommendations and conclusions are provided in Chapter 5.

II. SYSTEM OBJECTIVES AND REQUIREMENTS

A. INTRODUCTION

This chapter consists of three sections; system analysis, system objectives, and system requirements. The system requirements will be examined from the view of the LAN user. We will analyze the system in terms of the system elements and locations.

The following questions must be answered: Who will use the system? What does the system do? What are the objectives? Where is the system located? The answers to these questions will provide more understanding about the system.

B. SYSTEM ANALYSIS

The system analysis consists of the elements of the system and the locations of the system elements.

1. The system's elements

This section presents users and their functions.

a. Users

The system consists of ships, ships' departments and their headquarters. The ship's departments consists of four departments. The headquarter (HQ) consists of four staffs. Figure 1 shows the structure of the organization.

b. Functions

The headquarters staff and the ship's departments perform their own functions and the following administrative activities:

- Official letters and endorsements including memos.
- Staff/department studies and equipment reports.
- Bulletin and publications orders.
- Messages.
- Classified documents.
- Routine administrative forms.

The headquarters staff which includes operation, engineering, personnel, and logistic performs the following functions;

1. *Operations*: The operation staff is responsible for the operations, plans, organization, intelligence matters and personnel training.

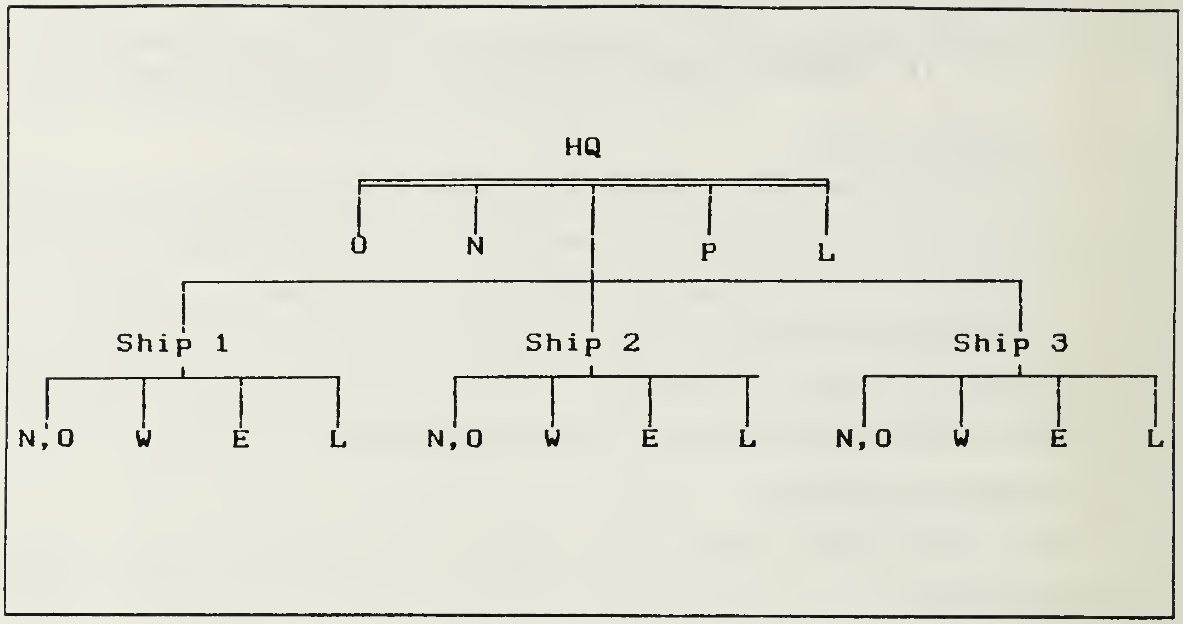


Figure 1. Structure of the organization

2. *Engineering*: The engineering staff is responsible the matters of maintenance, malfunctions, and equipment management.
3. *Personnel*: This staff is responsible for personnel services, facilities, personnel reports and personnel records.
4. *Logistic*: The logistic staff is responsible for supply, transportation, for equipment service, budgets and stock levels.

Ships operate under the authority of an officer ordered to command. He is called "captain". The commanding officer is the line officer in actual command of a ship.

The ships have these basic departments: Operation-Navigation, Weapon, Engineering, and Supply. Each ship's department has a department head, an officer who is responsible for its organization, training, and performance. The ship's departments perform the following functions:

1. *Operation-Navigation*: This department is responsible for safe navigation; plotting ship's position; collecting, evaluating, disseminating tactical and operational information; coordinates and plans for officer and enlisted education programs; and keeps the intelligence reports.
2. *Engineering*: This department is responsible for operating and maintaining the ship's machinery, power lighting, water maintenance and underwater fittings, and for preparing the machinery reports.

3. *Weapon*: This department supervises and directs the use of ordnance and ship equipment and is responsible for gunnery, deck seamanship, ordnance equipment and ammunition, and prepares the ammunition and gun reports.
4. *Supply*: This department handles the procurement, stowage and issue of all stores and equipment of the command. It pays the personnel salaries, and keeps the stock levels above the specified levels.

2. Locations of the system

The system will be located in the ships and on the land. The ships are located at the dock. The HQ is about 1 kilometer from the ships. The distance between ships is about 100 meters, and the distance between the departments of the ship and HQ is about 100 meters.

C. SYSTEM OBJECTIVES

The primary mission of the Navy is in maintaining our national security; it protects us against our enemies in the time of war, and improves combat readiness.

These missions will be maintained through the network. We list the following objectives about combat readiness and office automation.

1. The fast exchange of current information.
2. Fast and accurate decisions about the enemy.
3. Reduced time for cooperation between system elements.

Office automation refers to the aggregation and integration of several applications of computers and networks in office work. The aim is to help the office worker to perform the routine administrative functions of his/her job faster and more effectively.

The majority of normal office functions can be broken down into four basic activities: document preparation, message distribution, information management, and information access. These functions lead to the following objectives.

1. Increase the communication efficiency, decrease the processing time and leave more time free for creative thinking.
2. Transfer routine tasks to computerized systems.
3. Use the computerized system for locating reports.

In order to achieve these objectives, the authors will design a LAN, connecting the locations which are indicated above, and recommend a particular LAN.

D. REQUIREMENTS

1. User's requirements

A local area network provides a data communication system that allows transmission, storage and processing of data.

The users of this system will be military personnel, so the user's requirements will have some of the military characteristics. We can state the following users' requirements:

a. Document/message processing

- Word management (editing, deletion, formatting, inserting).
- Electronic filing (information storage and retrieval) .
- Quality print capability.
- Automatic generation of charts and graphs.
- Automated file indexing.
- Computation capabilities.

b. Document/message transmission

- Electronic mail.
- Automatic distribution list (directory of users).
- Acknowledgement/unacknowledgement of receipt.
- File transfer.
- Facsimile.
- Store and distribute message.

c. Document/message management

- Centralized and automated file access (searching and retrieval).
- File storage.
- File purging.

2. LAN requirements

This section will describe the LAN requirements.

a. Services

Network services refer to the functions performed by the network. Services are provided to the network by the protocols. The ISO model has a seven layer communication structure, each layer provides a set of services to the adjacent layer. If the system requires additional service for specialized application (facsimile, file transfer, word processing, electronic mail) the network requires additional software which can provide the ISO model with higher layer functions.

b. Information transmission

We can transmit four types of information (data, voice, video, and imagery) through the network. Each one has its own characteristics. Each one requires different data rates and buffer handling techniques.

Data has the following typical attributes:

1. Message transfer are relatively short transactions, often less then 4000 bytes in length. They include status and control, terminal commands , results, data base access commands, and human message interchange.
2. File transfers (stream traffic, bulk transfers); application includes data base results, archiving, inter-process file communication [Ref. 1: p.58].

c. Traffic

The network must provide the necessary protocols which are the transport and the protocol layers for imagery traffic. Two types of communication contribute to typical traffic paterns:

1. interactive users at CRT terminals to/from host computers.
2. computers to/from other computers or intelligent devices.

In the first case, terminals operating at data rates in the 9.6 Kbps to 19.2 Kbps range offer bursty traffic to the network. In the second case, computers offer higher data rates.

Terminal to computer communications are typically transaction oriented or bursty, and include data entry, word processing, program development, database access, and remote job entry.

Applications in which computer-to-computer communications take place are high speed; they consist of:

1. File transfer.
2. Distributed processing, including inter-process communications.

Computer-to-computer interactions take place at the maximum speeds allowed by the computer and network architectures (10 Mbps, typical).

The volume and characteristic of network traffic define the communications paths and associated performance requirements. The network must be capable of handling the data rates typical of the traffic type to be supported. Determination of the traffic throughput involves the collection of application traffic statistics which is shown in Table 1 [Ref. 2: p.179]. In Table 1, duty factor means the percentage of peak data rate can be transmitted continuously by a user of related application.

Table 1. INPUT LOAD

Service	Peak data rate (kbit/s)	Duty factor (%)
Heat/vent/air alarm security	0.1	100
Line printer	19.2	50-90
File/block	20 000	0.1
File server/transfer	100	10-30
Mail server	100	30-50
Information/calendar server	9.6	1.5
Information server/decision support	56	20-40
Word processor	9.6	1-5
Data entry terminal	9.6	0.1-1
Data enquiry terminal	64	10-30
Program development	9.6	5-20
Laser printer	256	20-50
Facsimile	9.6	5-20
Voice immediate	64	20-40
Voice store and forward	32	30-50
Video/noncompressed	30 000	50-90
Video freeze frame	64	50-90
Video compressed	400	20-40
Graphics noncompressed	256	1-10
Graphics compressed	64	10-30
Optical character reader	2.4	50-90
Gateway	1 000	0.1-1
Host 0.5 MIPS	128	20-40
Host 5 MIPS	1 000	20-30

Traffic patterns into and out of each user device are estimated to determine the required speeds and capabilities of the network. The traffic exchanged between a user device and the network is the sum of the traffic of that device's individual applications [Ref. 1: p.65]. The detailed network traffic is shown in Appendix A.

d. Security and privacy

The military organization needs different levels of security to protect from unauthorized attemps to access to classified information. In general network security can be defined as the protection of network resource against unauthorized disclosure, modification, utilization, restriction or destruction [Ref. 3: p.336].

Security also means the protection of ships, stations and property. There are three classification designations in the military organizations.

1. Top secret
2. Secret
3. Confidental

There is another category of information for official use only: unclassified.

In the case of a military network, regardless of the level, all classified information must be protected against unauthorized disclosure and it requires protection in the interest of national security.

e. Reliability

Reliability is the probability that a system or component will perform its specified function under specified conditions [Ref. 3: p.327].

The reliability of a network depends on the reliability of its components. A node or link failure will affect the reliability of the system. The topology will be selected so that a failure has the least impact on network operations and other systems. In the military organizations high system reliability is essential.

f. Interconnections

The network may require communication to the other networks which includes communications to other LANs or to WANs.

The Turkish Navy will require a military network which includes all components of the Turkish Navy, in the future. In this thesis the LAN will be a part of such a military network. Interconnection between the networks requires gateways.

g. Interfacing

Each device in the network requires specific interface protocols to communicate with other devices. Each network interface unit has to handle data at different receive and transmit rates.

To ease the burden on data processing equipment manufacturers and users standards have been developed that specify the exact nature of the interface between the equipment. A variety of standards for interfacing exist. For this reason it is expected that interfacing between the element of the proposed LAN will not be difficult.

3. Evaluation of the LAN

1. The capability of the network has to meet user needs.
2. The network has to be flexible to meet changing Turkish Navy requirements.
3. In order to reduce user problems, the system has to be simple.
4. The system has to exchange information between a variety of equipment. This requires compatibility.
5. The network has to be standard to provide vendor independent and universal level of communication.

We can state the following parameters to define the framework for the proposed LAN.

- Maximum node-to node distance - 1 kilometer
- Number of connected nodes - 20 nodes
- Data transmission rate - exceeding 1 Mbps
- Low error rates - no more than 10^{-9}
- High system reliability
- High system availability - not less than % 95

III. INTRODUCTION TO LAN

A. INTRODUCTION

This chapter will introduce the LAN. The first section of this chapter deals with LAN objectives and second section deals with design issues. The second section incudes topology, access methods, transmission medium, communication channels, LAN protocols and PC network configurations.

B. LAN OBJECTIVES

Local area networking is a form of computer communications generally used for the internal transfer of data and information. A LAN will accomplish several objectives and benefits, which are shown below for a Turkish Navy base.

1. Peripheral sharing

Network computers can share the services of printers, hard disks, modems, and other peripherals. Divided among all the PCs on the network, the per unit costs of these expensive peripherals is significantly reduced. Shared resource can also increase productivity [Ref. 4: p.169].

2. Information sharing

A LAN allows program and file sharing rather than each PC creating and storing its own files on separate storage media. Any user can have access to the files according to the security level permitted for the individuals by the Department Of Navy regulations.

C. LAN DESIGN ISSUES

There are many design issues in local networking. These are network topology, media, access methods, and standards.

1. Topology

The topology of a data link refers to the physical arrangement of stations on a link. Network topology describes how the stations of the network are inter-connected. The topology determines the network in terms of reliability, expandability, and performance. The topology is classified into four basic categories; bus, tree, star, and ring. Figure 2 illustrates these topologies [Ref. 5: p.329].

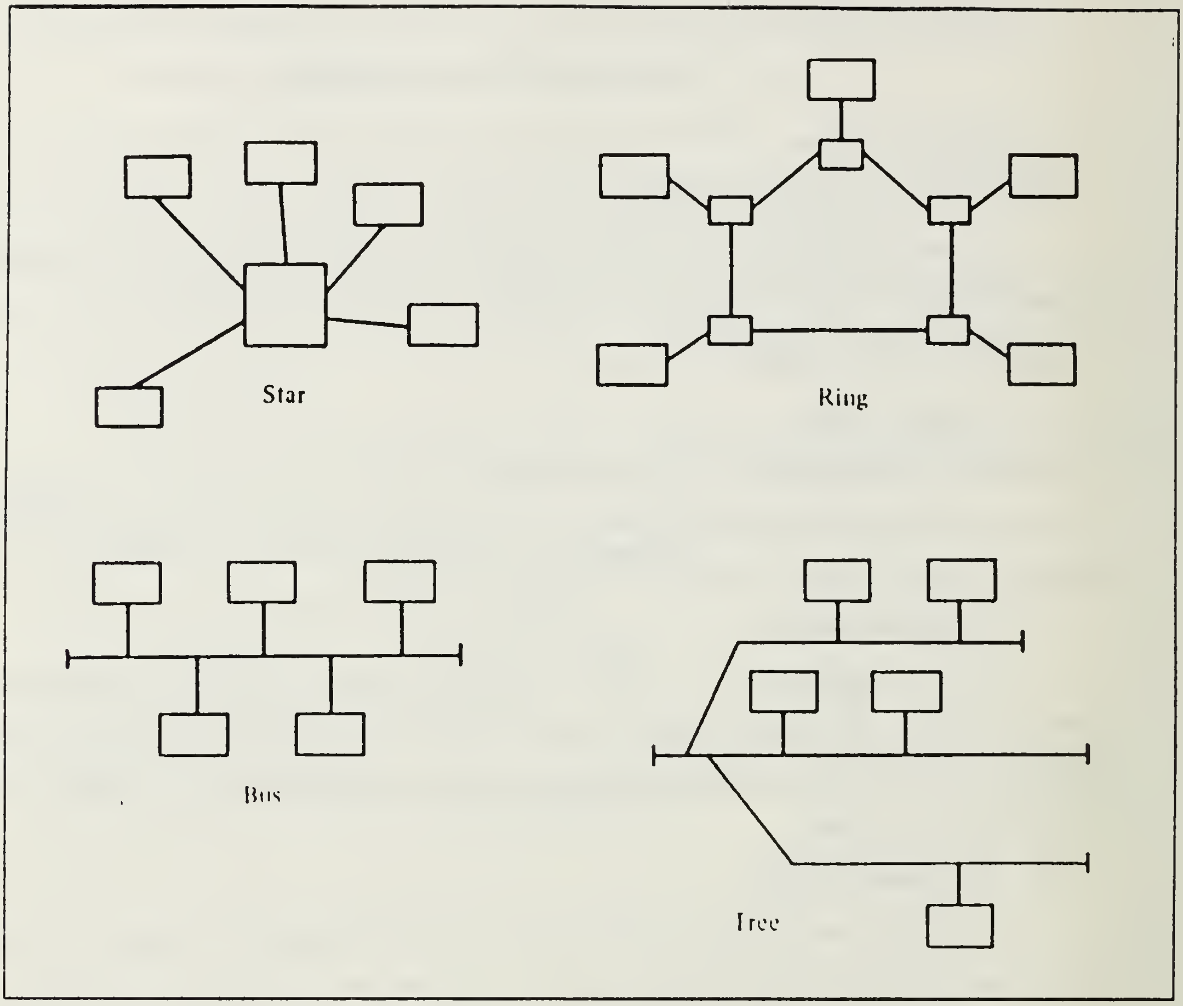


Figure 2. LAN Topologies

a. Bus Topologies

In a bus topology, illustrated in Figure 2, there are no routing decisions required by any of the nodes. A message flows away from the originating node in both directions to the ends of the bus. A node must be able to recognize a message intended for it. All stations share a full duplex transmission medium and receive all transmissions.

b. Tree Topology

The tree topology is shown in Figure 2 which is generalization of the bus topology. A transmission or a message from any station can be received by all other stations and propagate throughout the medium.

c. *Star Topology*

In the star topology, illustrated in Figure 2, there is a central switching node which provides communication between any two stations. Each station is connected by a point to point link to a central node. Nodes do not have to make routing decisions.

d. *Ring Topology*

The ring topology consists of a closed loop. Each node is attached to a repeating element. Data circulates around the ring on a series of point to point data link between repeaters. A station wishing to transmit waits for its turn and sends data [Ref. 5: p.340]. Ring topology is shown in Figure 2.

2. Transmission Media

The transmission medium is the path between nodes of the network. The media that have been used in local networks include twisted-pair wire, coaxial cable, and optical fiber.

a. *Twisted-pair wire*

One or more pairs of cable are enclosed within a single outer sheath. Twisted-pair cable in generally used for analog signals but has been successfully used for digital transmission. It is flexible and easily installed. The maximum transmission speed is less than coax, approximately 1 Mbps over a distance of 1 km. It is typically used for connecting computer peripherals and modems and computer systems. Environmental noise can effect the twisted-pair wire. With conduit shielding the curse of environmental noise on twisted-pair can be lessened.

b. *Coaxial Cable*

Coaxial cable is the most popular medium for LANs. The cable has an inner conductor (wire) with an outer conductor concentric with and completely surrounding it, which is usually grounded [Ref. 1: p.40]. Between the inner and outer conductor is a dielectric. It is expensive and difficult to install. The impedance is 50 ohm or 75 ohm which is use for LAN applications. Cable television networks (CATV) use 75 ohm coaxial cable, that has a bandwidth of more than 300 Mhz; 75 ohm cable is used for analog signaling with FDM, called broadband. Baseband 50 ohm coaxial cable can easily transmit information at 10 Mbps.

c. *Optical Fiber*

An optical fiber has a center core of a glass or plastic material surrounded by a cladding layer. Optical fibers transmit light instead of electric signal. It can transmit at a much higher bandwidth than coax. Light is not suspectable to electromagnetic interference. Error rates are very low. It can transmit at speeds of 200 Mbps over distance of 2 km. It has good security; the cable is not easily tapped. Fiber optics implementations are more expensive then twisted-pair and coaxial cable in terms of cost per foot of cable and required equipment.

3. Transmission techniques

There are two transmission techniques: baseband and broadband. Baseband, using digital signaling, can be employed on twisted-pair or coaxial cable [Ref. 3: p.75].

a. Baseband systems

Baseband refers to the transmission of an analog or digital signal in its original form. The entire frequency spectrum of the medium is used to form the signal; hence frequency-division multiplexing (FDM) can not be used. Transmission is bidirectional. The digital signaling requires a bus topology with contention control usually, CSMA CD. The system can extent only a limited distance, about 1 km. Baseband system is shown in Figure 3 [Ref. 3: p.77].

b. Broadband systems

Broadband implies the use of analog signals. FDM is possible. The frequency spectrum of the cable can be divided into data, TV, and radio signals. Much greater distance are possible, compared to baseband. A broadband system is shown in Figure 3 [Ref. 3: p.81].

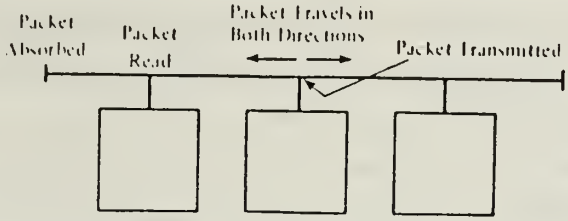
4. Medium access control methods

The access method itself is one of the most important aspects of local area network design. Since only one device can successfully transmits on the shared medium at a time, control is achieved with either acentralized a centralized or distributed method.

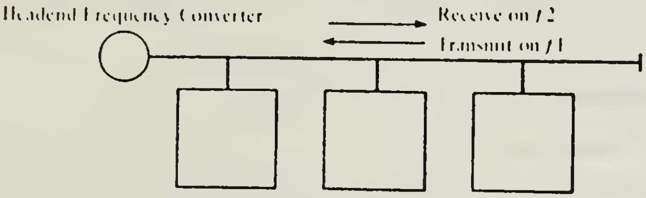
The three techniques, carrier sense multiple access with collision detection (CSMA/CD), control token, and slotted ring are used for local area networks.

a. CSMA/CD

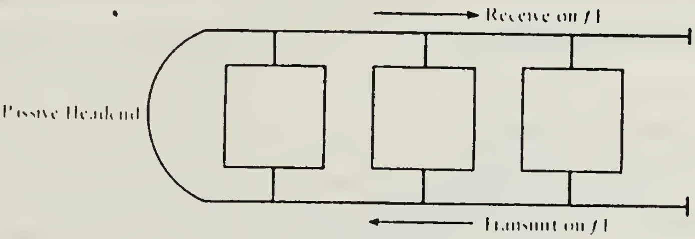
CSMA/CD is used with bus network topologies. A station can transmit if the line is free; otherwise, it must wait. The waiting station will either back off for a specified time interval before listening again or continuously monitor until the line is clear to send. Because of propagation delay, a station can not be certain that no other station is transmitting. Therefore collisions occur. If a collision is detected during transmission, transmission ceases immediately and a brief jamming signal is transmitted to assure that all stations know there has been a collision. After transmitting that signal, a station waits a random amount of time then attemps to transmit. The principal ad-



(a) Bidirectional (Baseband, Single-channel Broadband)



(b) Mid-split Broadband



(c) Dual Cable Broadband

Figure 3. Transmission techniques

vantage of CSMA/CD is simplicity, and its disadvantage is to increase the probability of collision under heavy load.

b. Control Token

The control token is used with either bus or ring networks. The control token is passed from one station to another. A station may only transmit, when it is in possession of the token, and after it has transmitted the frame, it passes the token on to allow other stations to access the transmission medium. This is a more complex and expensive technique than CSMA/CD. The control token has poorer performance than CSMA/CD at light loads and better performance at high loads.

c. Slotted ring

This method is used with a ring network. The ring is first initialized to contain a fixed number of binary digits by a special node in the ring known as a monitor. The format of a frame slot and topology outline are shown in Figure 4 [Ref. 6: p.211].

This stream of bits continuously circulates around the ring. All the slots are marked as full or empty. When a station wishes to transmit a frame, it first waits until an empty slot is detected. It then marks the slot full and indicates the source and destination addresses. The main disadvantages of the slotted ring are, firstly, a special monitor node is required. Secondly, each slot can only carry a limited amount of useful information; normally, multiple slots are required.

5. Communication Switching Techniques

Communication is achieved by transmitting data from station to station through a network of intermediate nodes. One purpose of the node is to provide switching facility that will move the data from node to node until they reach their destination. There are three switching techniques; circuit switching, message switching, and packet switching.

a. Circuit Switching

In circuit switching, a dedicated communication path is established between two stations before data transmission begins. There is an actual physical connection between two stations. Communication using circuit switching techniques involves three phases.

1. Circuit establishment: before any data can be transmitted, an end to end circuit must be established.
2. Data transfer: after circuit established, signals can be transmitted.
3. Circuit disconnect: after some period of data transfer, the connection is terminated.

These techniques are rather inefficient. Channel capacity is dedicated for the duration of the connection, even if no data are begin transmitted. Data are transmitted at a fixed data rate with no delay other than the propagation delay through the transmission links [Ref. 3: p.28].

b. Message Switching

In message switching, when a station wishes to send a message it appends a destination address from node to node. At each node, the entire message is received, stored briefly, and then transmitted to the next node. This system is also known as a store-and-forward message system.

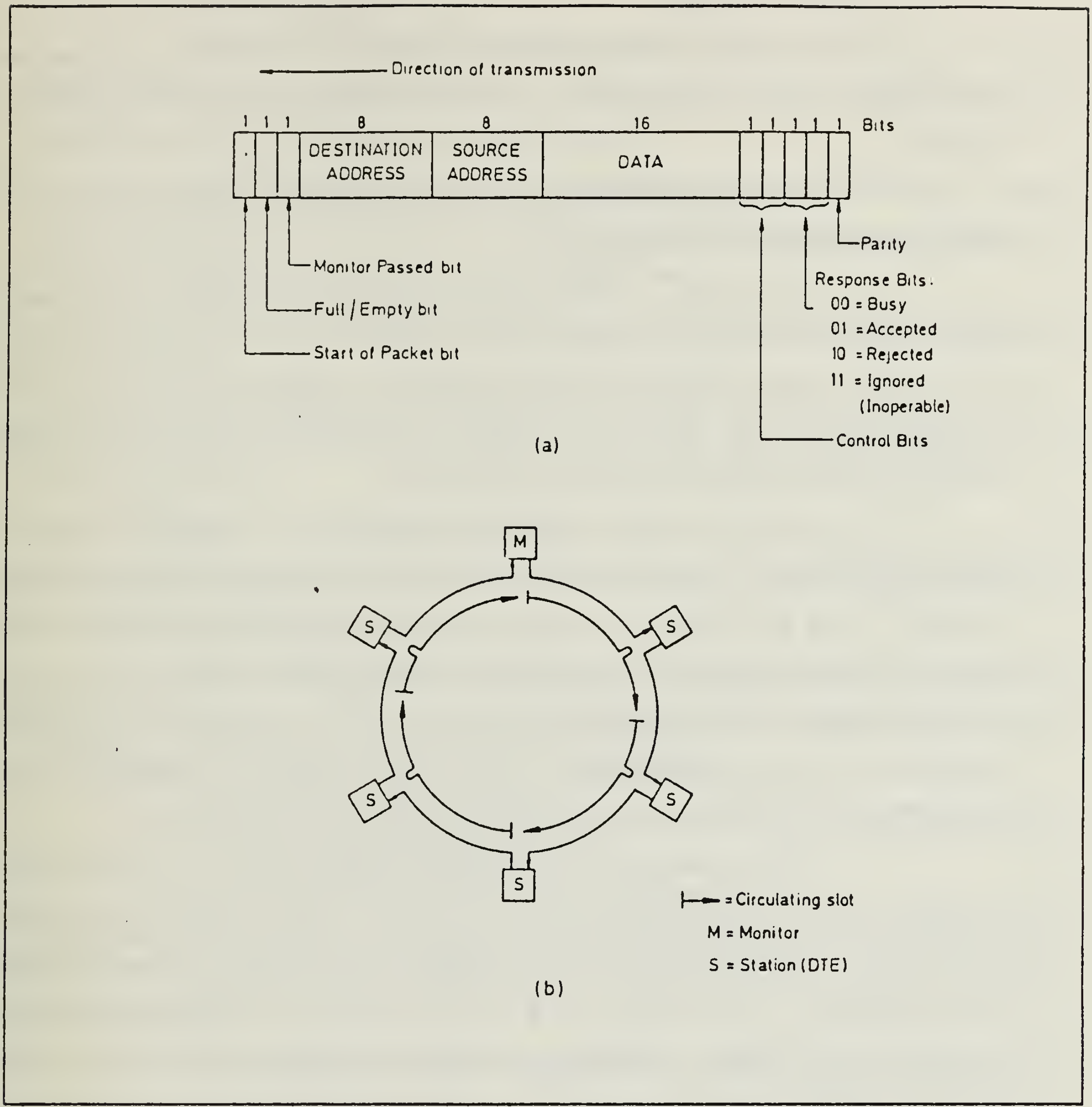


Figure 4. Slotted ring

The basic advantage of this approach over circuit switching are: line efficiency is greater, simultaneous availability of sender and receiver is not required, heavy traffic messages are still accepted (but delivery delay increases), one message can be send to many destinations, and message priority can be established [Ref. 3: p.29].

c. Packet Switching

This technique is commonly used in LAN environments. A message must be divided into smaller units (packets). A copy is temporarily stored for error recovery purposes.

For handling entire messages over a packet switched network, there are two approaches: datagram and virtual circuit.

(1) Datagram: Each packet is treated independently. So the packets, each with the same destination address, do not all follow same route. Thus it is possible that the packets will be delivered to the destination in a different sequence from the one in which they were sent. The way of reordering the packets depends on the network computer system and higher-level software protocols.

(2) Virtual Circuit: A logical connection is established before any packets are sent. But this does not mean that there is a dedicated path, as in circuit switching. In the X.25 version of packet switching, each packet is contains a virtual circuit identifier as well as data. Each node on a pre-established route knows where to direct such packets. No routing decision is required. One of the stations terminates the connection with a clear request packet. If two stations wish to exchange data over an expanded period of time, there are certain advantages to a virtual circuit.

One advantage of the datagram approach is that the call set up phase is avoided. Thus if a station wishes to send only one or a few packets, datagram delivery will be quicker. Another advantage of the datagram service is that, because it is simpler, it is more flexible. If a node fails, in a X.25 virtual circuit, all virtual circuits that pass through that node are lost. With datagram delivery, if a node is lost, the packet can find another route [Ref. 3: p.32].

6. Network Standards and Protocol Architecture

The desired goal is to establish a local area network specification with recognized interface and protocol standards that will allow networks and devices from different vendors to communicate with each other. When communication is required among the different devices, there are few hardware problems. But, software can be a big problem. Communication is possible with a common set of rules. The network requires standards.

a. The OSI Layers

The open system interconnection (OSI) specifies an architecture for open system communication. This model, used as a reference in comparing different protocol architectures, allocates functions to protocol layers.

The OSI model, by defining a seven-layer architecture, provides a framework for defining these standards. Each of its seven layers focuses on the needs of a specific area within networking. These seven layers are:

Layer 1-The physical. Describes the physical and electrical connections among stations.

Layer 2-The data link. Describes the method by which information is packaged before transmission and disassembled upon reception. Responsibility of both software and hardware.

Layer 3-Network layers. Defines how the most economical and efficient transmission lines are accessed in the transmission medium. Network layers functions are usually software driven.

Layer 4-Transport layer. Monitors the transmission between the stations after the path has been selected. Insure the reliability of the system during a data transmission. A function of both hardware and software.

Layer 5-Session layer. Insures that a station wanting to communicate is set up to do so. Usually a software responsibility.

Layer 6-Presentation layer. Translates data into a format that can be viewed and manipulated by a receiving station. For example, the translation of data generated by one database manager to run on another database manager. Most often done by software.

Layer 7-Application layer. Governs how useful application software is to the overall functioning of the network [Ref. 4: p.184].

The OSI reference model is shown in Figure 5 [Ref. 7: p.16].

Essentially, the lowest three layers are concern with the communication protocols associated with the data communications network . The upper three layers are concerned with the protocols necessary to allow two heterogeneous operating systems to interact with each other. The intermediate transport layer then makes the upper protocol layers from the detail workings of the lower network-dependent layers.

The function of each layer is formally specified in the form of protocol which defines the set of rules and conventions which are used by the layer in order to

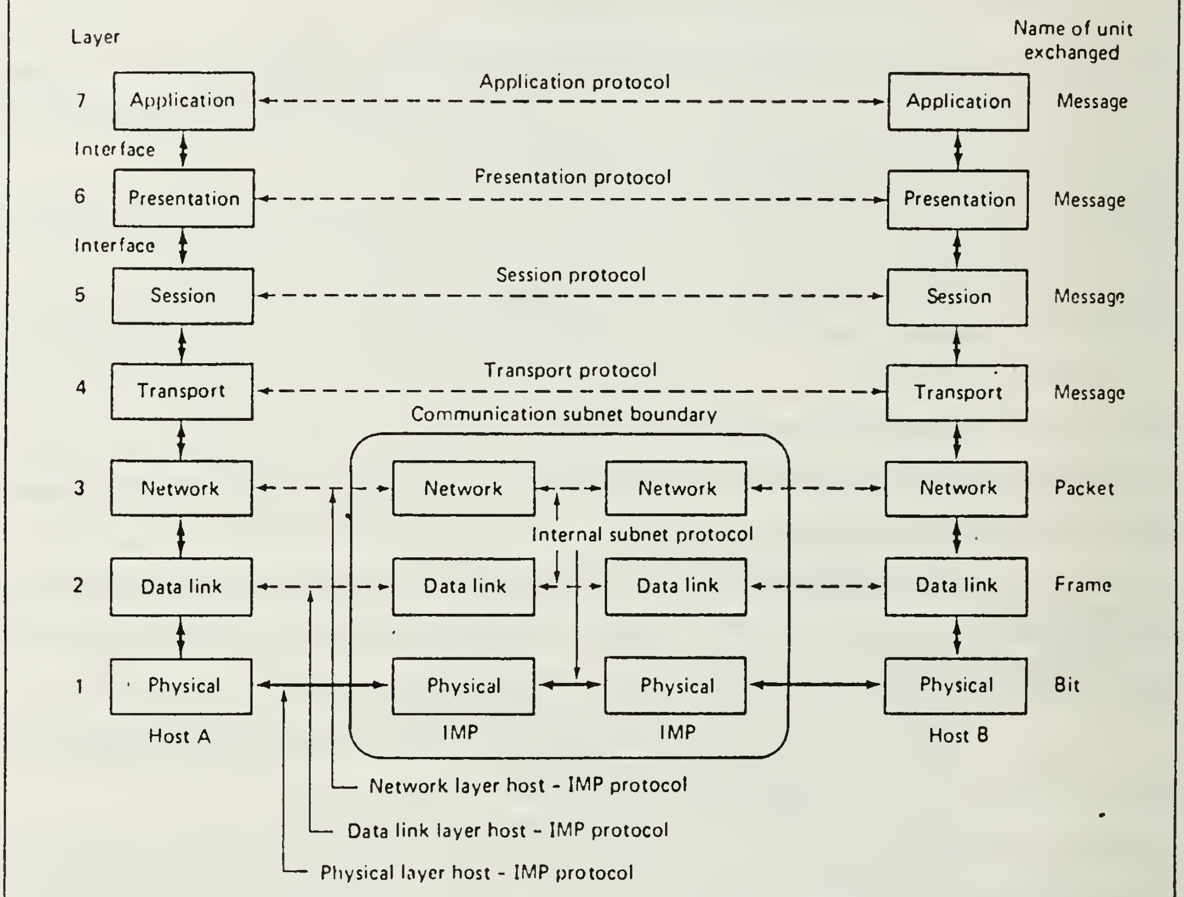


Figure 5. OSI Reference Model

communicate with a similar layer in another system. Each layer provides a defined set of services to the layer immediately above it, and in turn, use the service provided by the next lower layer to transport the message units associated with the defined protocol of that layer.

b. The LAN protocols

LAN protocols can be divided into two basic levels: low-level and high-level protocols. The function of low-level protocols is to transport groups of bits through the network. The other function of the low-level protocol is to support high-level protocols. The work of the IEEE on the 802 series of standards for LAN protocols is only concerned with the lower layers of the models, and deals with the physical layer (voltage, waves forms, etc.) and the media access (resolution of contention for the common medium, physical address). The LAN standards generally regard the second layer of the ISO model as split in two and define separate protocols for the media access and the link. Figure 6 shows the relationship between the OSI model and LAN protocol layers of the IEEE 802 [Ref. 8: p.357]. The higher layer protocols must then be obtained from standards prepared by the ISO.

As shown in Figure 6 the function of the ISO data-link layer is part of the logical link control and part of the media access control of the IEEE 802.

The medium access control layer provides for use of a random access or token procedure for controlling access to the channel and also includes addressing of the data frames and frame-check sequences. The logical link control layer provides a basic data-link protocol with at least two kinds of service.

- Unacknowledged connectionless service, which is similar to the datagram service.
- Connection-oriented service, which is similar to the virtual-circuit service.

7. Interface/Internetworking

a. The network interface unit (NIU)

The NIU is a microprocessor device. The NIU acts as a communication controller to provide data transmission service to the attached device. The NIU transforms the data rate and protocols of the subscriber device to that of the local network transmission medium and vice versa. The NIUs control access to the communication channel across the local network. Subscriber device attach to the NIU through the some standard communications or I/O interface. The NIUs accept data from attached device, buffer the data until medium access is achieved, transmit data in addressed packets, scan each packet on medium for the devices own address, read packet into buffer, and transmit data to attached device at the proper data rate [Ref. 3: p.209]. Figure 7 shows an architecture for a NIU.

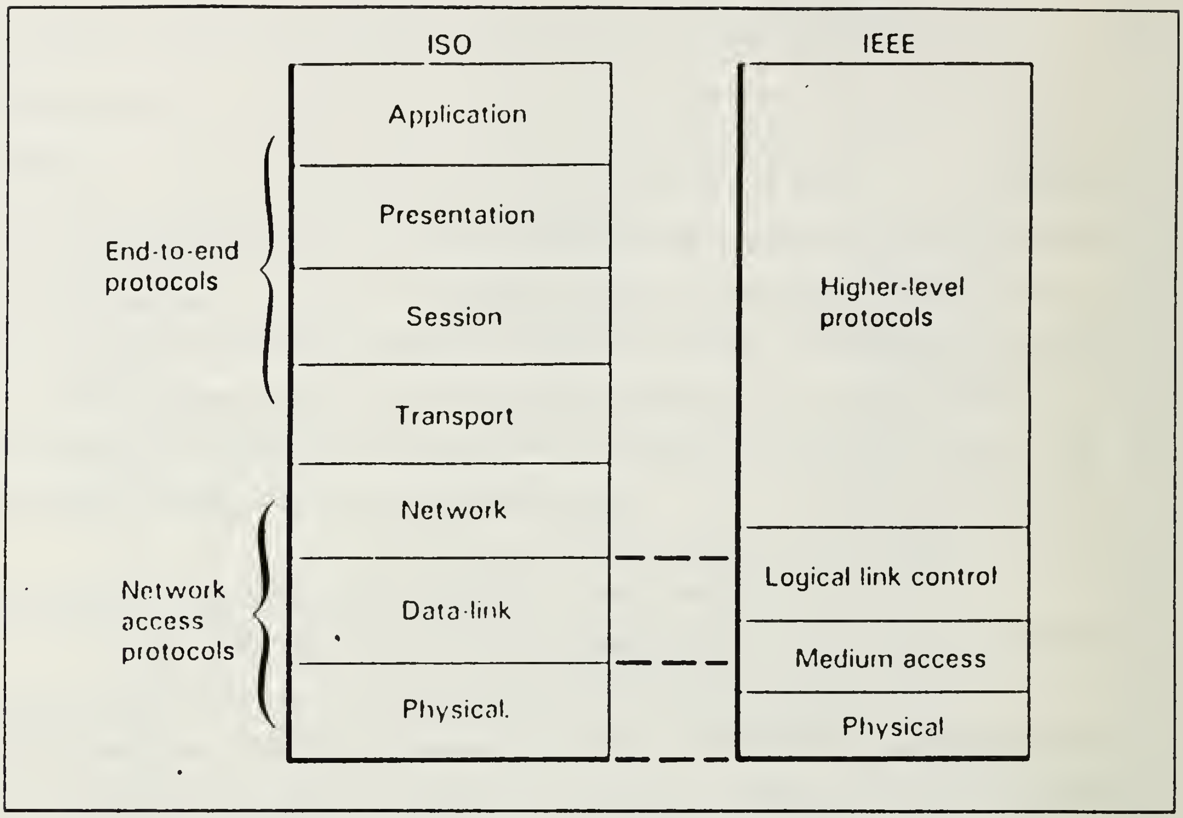


Figure 6. OSI Model and LAN

b. Network Nodes

Network nodes (to which stations are attached) form the boundary of a network.

Bridges and gateways are two type of nodes which provide specific service to networks.

Networks are interconnected through gateways. The function of gateway nodes is packet conversion, addressing and routing.

Gateways are used for connections between dissimilar LANs, and between LAN and long haul networks of different architectures.

The bridge is used for interconnecting two networks with identical architectures. A bridge offers more functionality than a repeater. A system with throughly separate but homogenous networks reguires a bridge to connect them. Interconnecting two or more LANs would require a large backbone LAN. Figure 8 illustrates the types of interconnections of LANs.

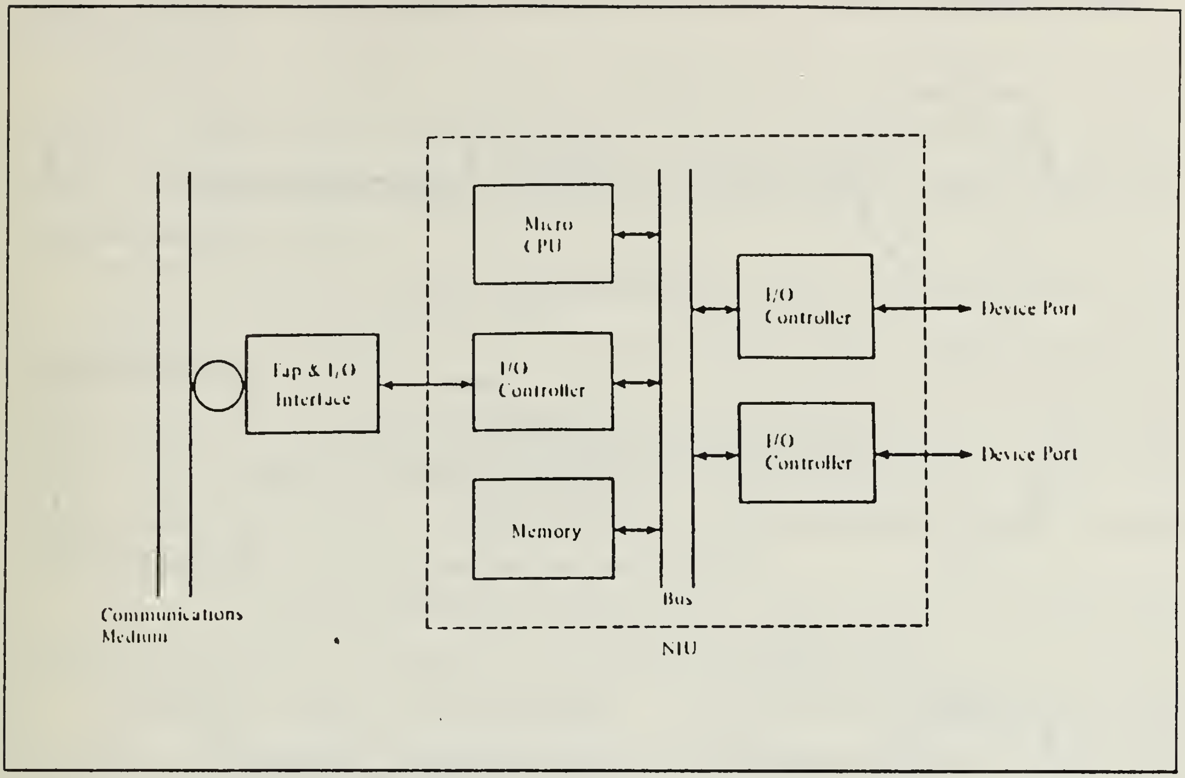


Figure 7. NIU Architecture

An individual PC equipped so it can connect to a LAN normally has just one network adapter. However, it's possible for two networks to be linked by a single PC that acts as a bridge/gateway between them, just as a PC can function as a file server or print server. The PC that acts as bridge must be dedicated: that is, it can't handle anything else while it's acting as a bridge. The PC bridge contains interface cards for two networks. They may be on the same or different networks.

8. PC Network Configurations

Before setting up the network, we need to give some answers to key questions. These are:

- How many users will there be?
- How many servers will there be?

There are no precise rules for deciding these questions. The IBM PC network program allows for one of four different types of configurations for each work station. There are three levels of user configuration and one configuration for servers. The different kinds of user configurations are: messenger, receiver, redirector. The server con-

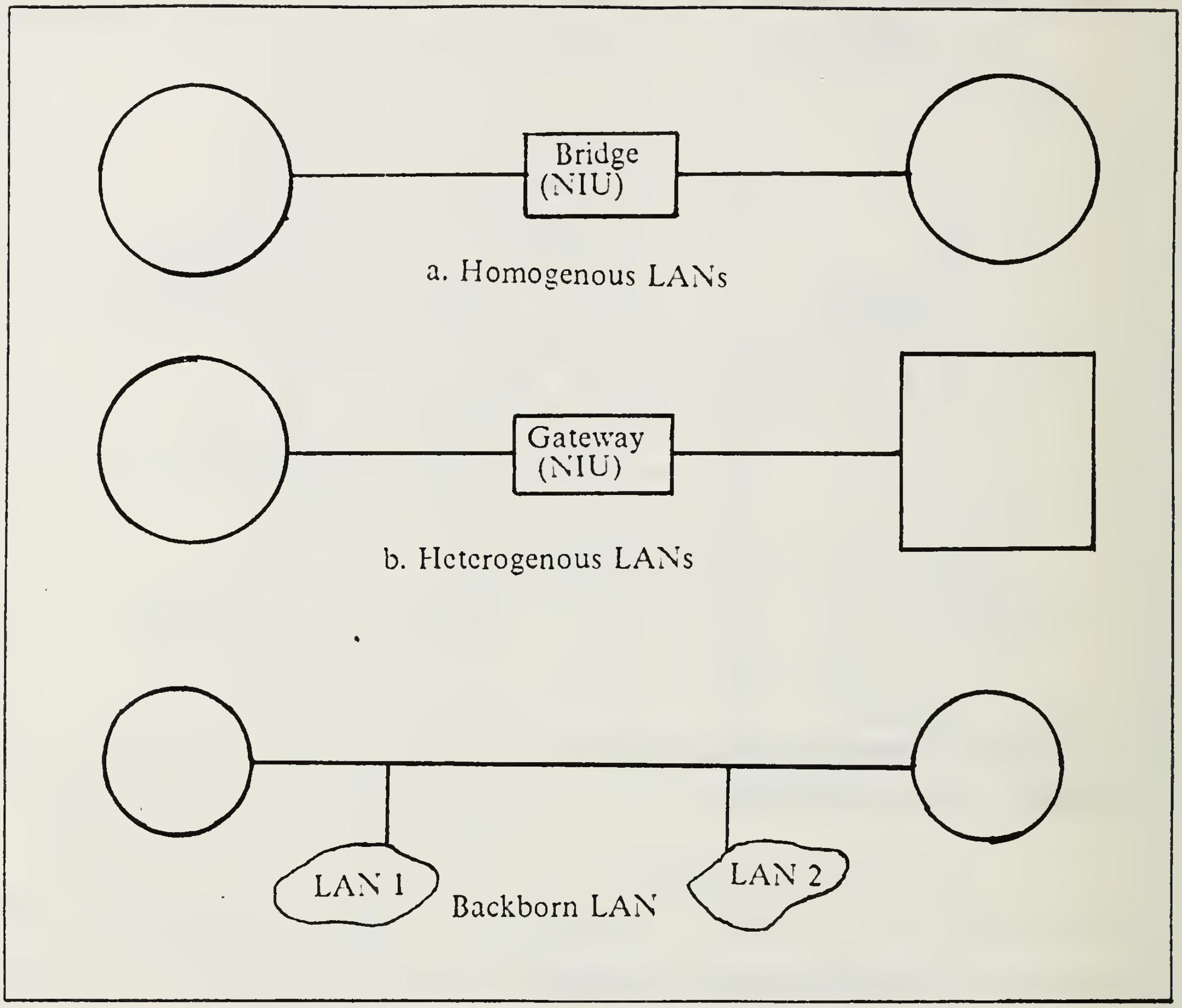


Figure 8. The Types of Interconnection of LANs

figuration allows user computers to use its fixed disk and printer. Every configuration can send messages. However, a redirector cannot receive messages, and a receiver can not forward messages to another workstation.

a. Servers

The PC network will allow us to use some application programs such as DBase 3 plus, Wordperfect, and Lotus. We can access these programs through the server. This computer allows us to share its resources.

One server may function simultaneously both as file and print server. The network file server software is usually stored on a hard disk drive controlled by the file server. A file server contains disk spaces that are accessible to other PCs on the network. A print server has a printer or other hardcopy device that can be used by any PC on the network.

(1) File servers: Any file on the file server's disk can be read or copied by any PC in the network. The file server also maintains control of file access. For example, a file server may offer password controls to ensure that only authorized personnel have access to certain files.

(2) Print servers: A print server allows users to share a printer. If users want to use a high-quality printer, they need to share a printer on the network, because these devices are more expensive than the normal printer. When a printer is shared among the users, they send their files to the computer (print server). The print server saves the files in a spool file, and then transmits the file from the spool to its printer. Thus, each computer that offers to share a printer must have a queue manager; It is built into the PC network software.

The same PC can play both roles at the same time; it can simultaneously provide resources to others and use services that others provide.

(3) Memory/disk requirements. To run network programs, share disk files, and store print files, a server must have at least 320k bytes of memory and at least one hard disk. Ideally, a server runs on a PC/AT with at least 512k bytes of memory [Ref. 9: p.41]. They should have as much memory as possible. A server must have a fixed disk that makes space available to other users by offering to share its directories. The transfer rates to the fixed disk of the IBM PC/AT is significantly faster than that of the PC/XT. Because of this, there is an advantage in using PC/ATs as file servers.

A server which is providing printer service passes user data through a set of buffers. Space for these buffers is set by default at 16k of main memory, but may be set as high as 48k [Ref. 10: p.209].

b. Users

A user uses a server's disk, directory or printer, and sends, receives and saves messages. As we stated earlier, there are three user configurations. Ecah one has different functions.

The messenger is the network configuration that has the most features after the server. The messenger can do everything a server can do, except share disks, directories, and printers. The messenger must have at least 256k bytes of memory. The receiver configuration is the basic network device type. Because of its limited capabilities, the receiver needs only 192k bytes of memory. The redirector is the most limited network configuration. Because of these modest network capabilities, the redirector needs only 128k bytes of memory [Ref. 9: p.42].

Each user needs two floppy-disk drives, one for programes and one for data. A floppy-disk drive allows a user to load programs not available in the directories of the server, and it is useful for copying data. For all these reasons, a user must have at least two floppy-disk drives.

IV. LAN SOLUTION

A. INTRODUCTION

This chapter discusses, firstly, the selection of design issues such as transmission medium, topology, transmission techniques, and access control methods; secondly, it will present a model of a LAN.

B. THE SELECTION PROCESS

The main design issues of LANs are: transmission medium, topology, transmission techniques, and access control. Table 2 presents options for each design issues.

Table 2. OPTIONS FOR DESIGN ISSUES

Transmission medium	Topology	Transmission techniques	Access Methods
coaxial cable	bus	baseband	CSMA/CD
twisted-pair wire	tree	broadband	token passing ring
fiber optics	ring		token passing bus
	star		TDM

1. Topology

The choice of topology depends on reliability, expendability and performance factors. The choice is part of the overall task of designing a local network.

The bus/tree topology appears to be most flexible one. It is able to handle a wide range of devices, in terms of number of devices, data rates, and data types. High bandwidth is achievable. Because the medium is passive, it would appear highly reliable [Ref. 3: p.57]. A topology decision tree is shown in Figure 9 [Ref. 11: p.28].

The advantages and disadvantages of each topology are given below:

1. Ring networks: Simplicity of access and transmission. No need for central control. Assured access to the network is provided. Bypass circuity and wire centers prevent the ring from failing if a node fails.
2. Bus/tree network: Distributed network control. Each station has equal control capability. Addition or deletion of stations seldom requires adjusment of the network.

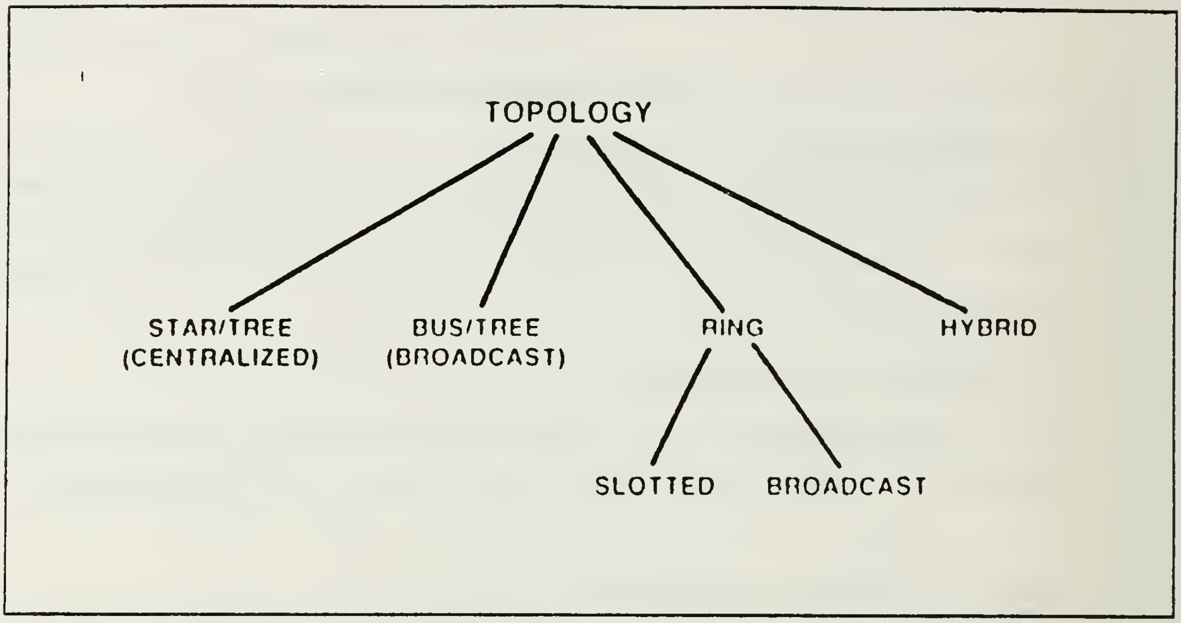


Figure 9. Decision Tree for Topology

3. Star topology: Low data rate due to the inability of the control node to support more than one conversation. If the central node is fails, it would halt all operations.

The choice of transmission medium and topology are not independent. Table 3 shows the relationship between medium and topology [Ref. 3: p.68].

Table 3. RELATIONSHIP BETWEEN MEDIUM AND TOPOLOGY

Medium	Topology			
	Bus	Tree	Ring	Star
Twisted-pair	*		*	*
Baseband coax.	*		*	
Broadband coax.	*	*		
Optical fiber			*	

After comparing the topologies, we chose a bus topology for easy expansion.

2. Transmission Medium

The media that have been used in local networks includes twisted-pair wire, coaxial cable, and optical fiber. Table 4 summarizes some of the important characteristics of the various media [Ref. 3: p.61]. The decision tree is shown on figure 10 [Ref. 11: p.30].

Table 4. CHARACTERISTIC OF THE MEDIA

Medium	Signaling Technique	Maximum data rate (Mbps)	Maximum range at maximum data rate (km)	Practical number of devices
Twisted-pair	Digital	1-2	Few	10′s
Coaxial cable (50 Ω.)	Digital	10	Few	100′s
Coaxial cable (75 Ω.)	Digital	50	1	10′s
	Analog with FDM	20	10′s	1000′s
	Single-channel analog	50	1	10′s
Optical Fiber	Analog	100	1	10′s

Types of transmitted information throughout LAN are data and imagery. We need to transmit voice and video in near future. Figure 11 shows product selection trees to determine the best medium for an environment [Ref. 12: p.174].

To decide which medium to select for a LAN, we move from left to right across the selection tree checking the distance, bandwidth, and applications supported by twisted-pair, baseband, and broadband. The optical fiber is currently best only for point-to-point communication. We chose a broadband coaxial cable, which offers sufficient bandwidth to support data, voice, and video. Baseband coaxial cable has only data and some limited voice capability.

Comparing the characteristics of transmission media and requirements of a LAN we selected broadband coaxial cable.

3. Transmission Techniques

There are two transmission techniques, baseband and broadband. The argument or tradeoff between the broadband and baseband is cost versus bandwidth, data rate.

Baseband employs much lower bandwidths-usually no more than 50 Mhz-and the bandwidth is taken up by transmitting one signal. The bandwidth of broadband signals is usually far greater than that of baseband. It is often the order of 300 Mhz or

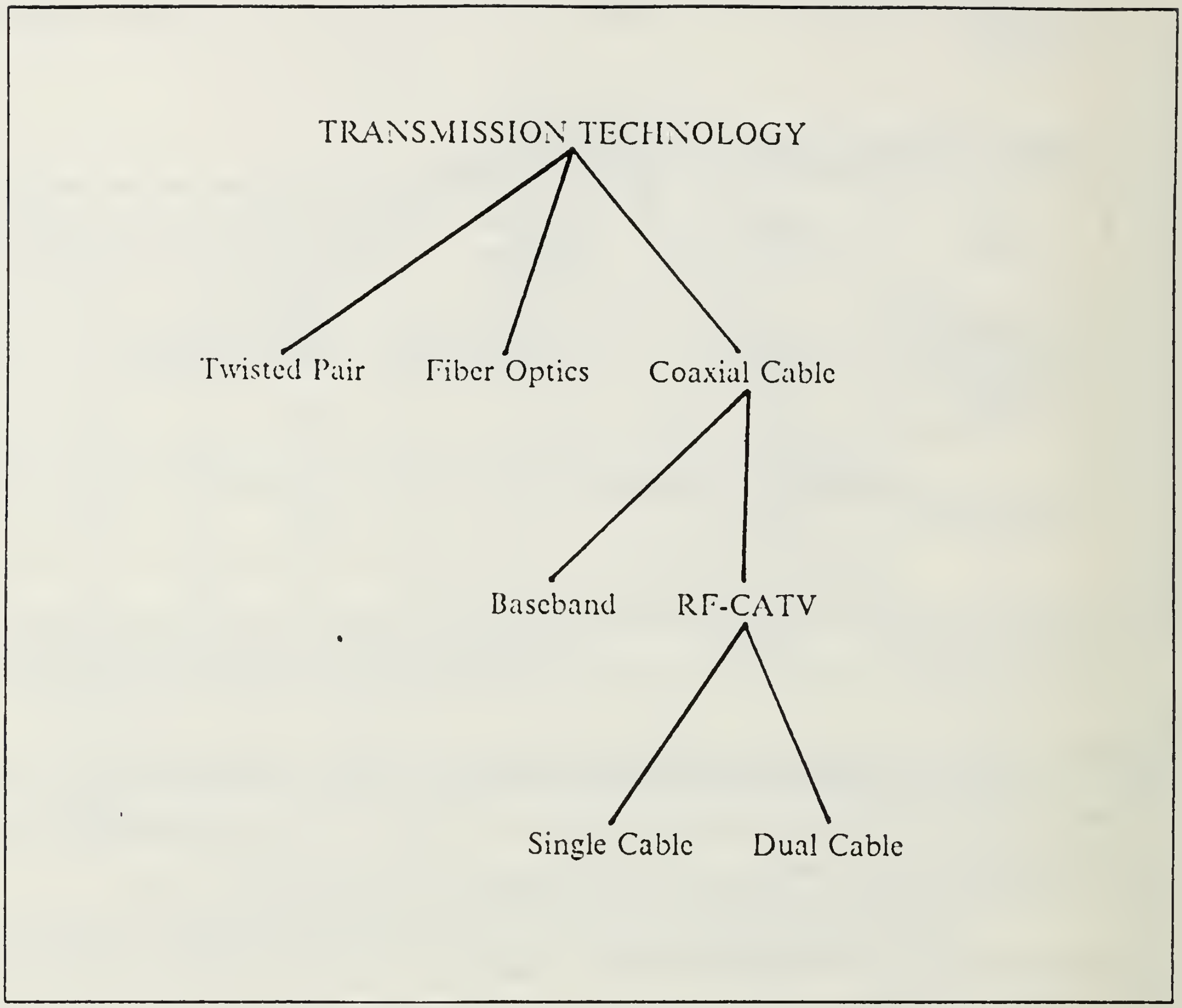


Figure 10. Decision tree for transmission media

more. The primary advantage of the broadband system is its handling of video transmission. Broadband systems usually have their available bandwidth broken up into a number of channels. Each of these channels has the potential for transmitting image, data, voice, and text.

The aim of broadband systems is to provide a LAN with the capability of handling large numbers of devices over distances up to ten miles and to carry data, image, and voice transmissions. Baseband systems are generally regarded as being insufficient for continuous video or voice applications. Yet, baseband systems are much less expensive and more available today. Table 5 shows the advantages and disadvantages of the two techniques [Ref. 3: p.87].

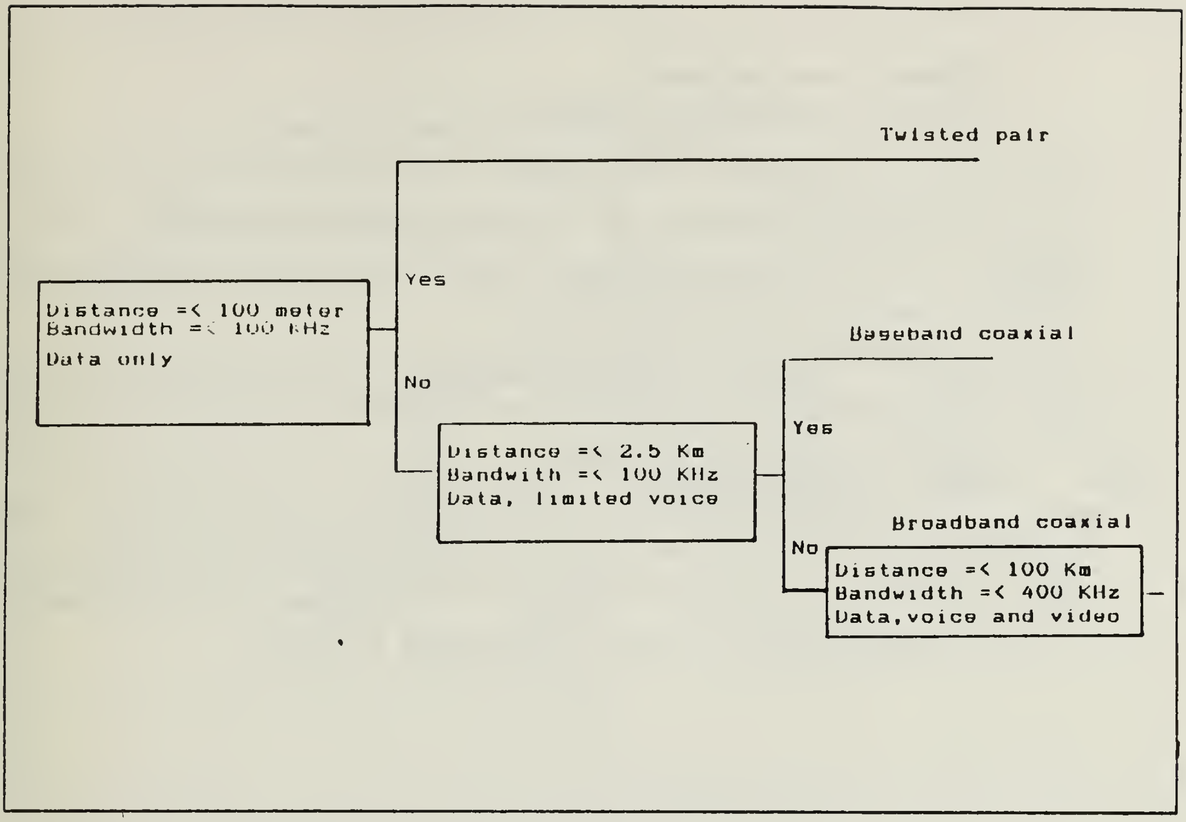


Figure 11. Selection tree for medium

We compared the characteristics of baseband and broadband systems. We considered requirements for a LAN, high capacity and multiple data types, and we selected broadband as a transmission technique for the LAN.

Table 5. BASEBAND VS BROADBAND

ADVANTAGES	DISADVANTAGES
BASEBAND	
Cheaper no modem	Single channel
Simpler technology	Limited capacity
Easy to install	Limited distance
	Grounding concerns
BROADBAND	
High capacity	Modem cost
Multiple traffic types	Installation and maintenance complexity

4. Channel Access Techniques

The decision tree for access method is shown in Figure 12 [Ref. 11: p.28]. The dedicated access method is not appropriate because it wastes resources and is inflexible for most office and data processing environments. Both controlled and random access are techniques which permit sharing of a high bandwidth medium by a multiplicity of contending users.

In controlled access, contention is reduced by polling or use of reservations. Roll-call polling assumes the centralized controller interrogates each subscriber separately and allocates the channel accordingly.

There is a correlation between network topology and access method. At present, CSMA/CD and token bus are two of the principal contenders for medium access control technique on a bus/tree topology. The advantages and disadvantages of CSMA/CD versus token bus is shown in Table 6 [Ref. 3: p.125].

Table 6. **CSMA/CD VS TOKEN BUS**

ADVANTAGES	DISADVANTAGES
CSMA/CD	
Simple algorithm	Collision detection requirement
Widely used	Fault diagnosis problems
Fair access	Minimum packet size
Good performance and low to medium load	Poor performance under heavy load
	Biased to long transmission
TOKEN BUS	
Excellent throughput performance	Complex algorithm
Tolerates large dynamic range	Unproven technology
Regulated access	

Token polling is more suitable for nodes with heavy traffic (for example, file transfers) and CSMA/CD is appropriate for a large number of bursty users (for example, in an office and interactive data processing environment). If we compare both access

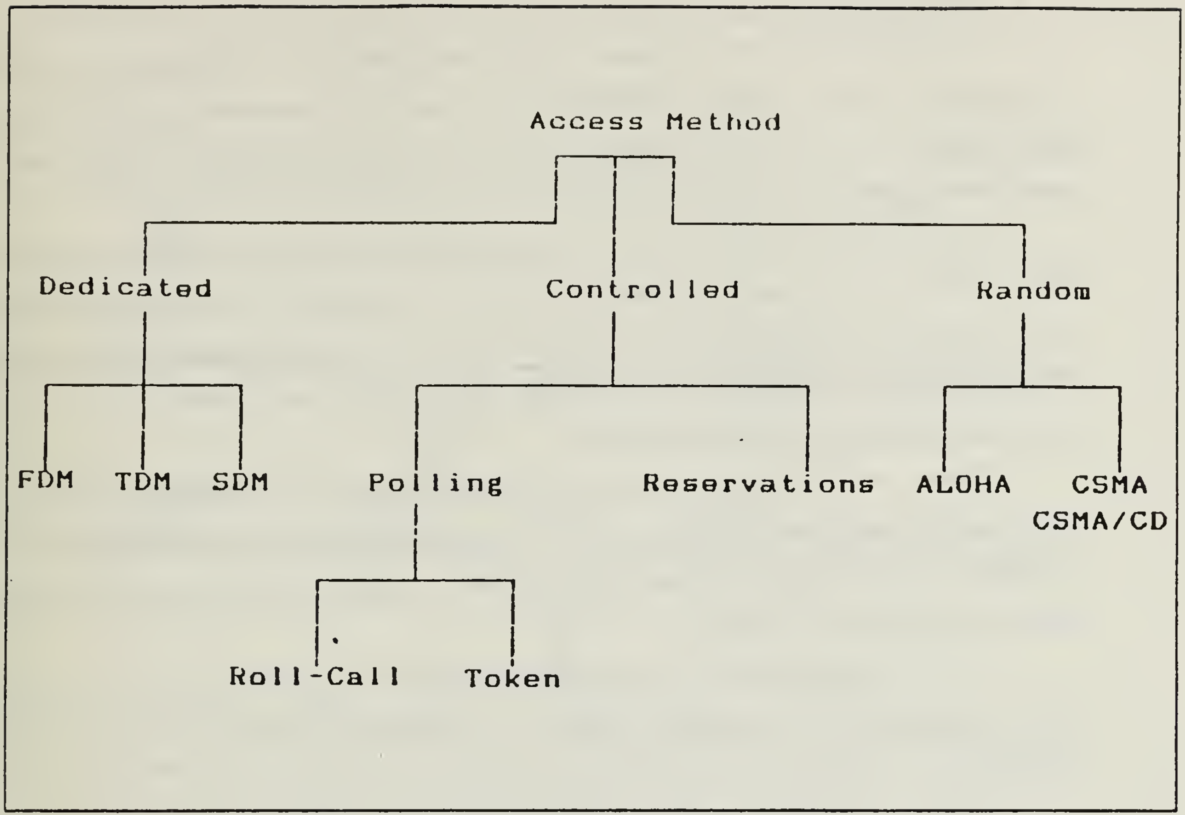


Figure 12. Decision tree for access methods

techniques, we select CSMA/CD as an access method which is suitable to our environment.

C. DESIGN ISSUES IN BROADBAND LOCAL NETWORKS

In the previous section, we selected a broadband LAN. Broadband transmission is performed in the VHF band by employing RF modulation. It can support multiple frequency division multiplexing (FDM) channels for data, voice, and video. Note that RF transmission requires separation of transmit/receive signals either via two separate cables, or by splitting the bandwidth of a single cable and translating transmit/receive signals at a headend.

1. Transmission Medium

Coaxial cable (75 ohm cable) is used as the transmission medium because of its capacity, available bandwidth of 300 to 400 Mhz, high speed data transmission rates and very low bit error rate.

2. Implementation

A broadband network carries mixed media services. The question of whether to use single or dual cable distribution, remains to be answered. To accomplish bidirectionality, two different cable schemes are used; single cable and dual cable as shown in Figure 3.

A dual cable network uses one cable toward the headend (for inbound carriers), and the other, created through a physical loop at the headend (for outbound carriers). The dual cable is represented by a single cable that loops at the headend, thus creating two separate paths, inbound and outbound. Single cable uses frequency-spectrum split to achieve bidirectional communication.

There are three frequency splits: sub-split, mid-split, and high-split. The available frequency range is split into a "return" band (from the user to the headend) and a "forward" band (from the headend to the user). Figure 13 illustrates frequency allocation for each [Ref. 13: p.110].

In the sub-split format, the total bandwidth of the return path is 25 Mhz and the total bandwidth of the forward path is 346 Mhz. Sub-split has been the most popular scheme.

In the mid-split format, the bandwidth of the return path is 103 Mhz, and the bandwidth of the forward path is 226 Mhz. It has greater available bandwidth for the return path. It allows for more duplex data communication links. IEEE committee 802, through it's TR 40.1 committee, has endorsed the mid-split format until a new high-split format is formally adopted.

In the high-split format, the available bandwidth is divided into two equal portions for the forward and return paths. The return bandpass is from 5 to 175 Mhz and the forward bandpass is from 232 to 400 Mhz. High-split networks are more appropriate for pure data communications than for mixed mode services.

Dual cable networks are less cost effective than single cable networks because they require twice the amount of hardware, to support the inbound and outbound cables. The single cable networks have half the number of components of the dual cable. Studies indicate that an average of only 35 percent of the total available bandwidth is currently being used in broadband local networks [Ref. 13: p.114].

There are exceptions, but generally only a fraction of the available bandwidth is needed in each direction to meet the requirements for most local networks for data, voice, video, and control. Single cable networks fit, especially if the network is to be

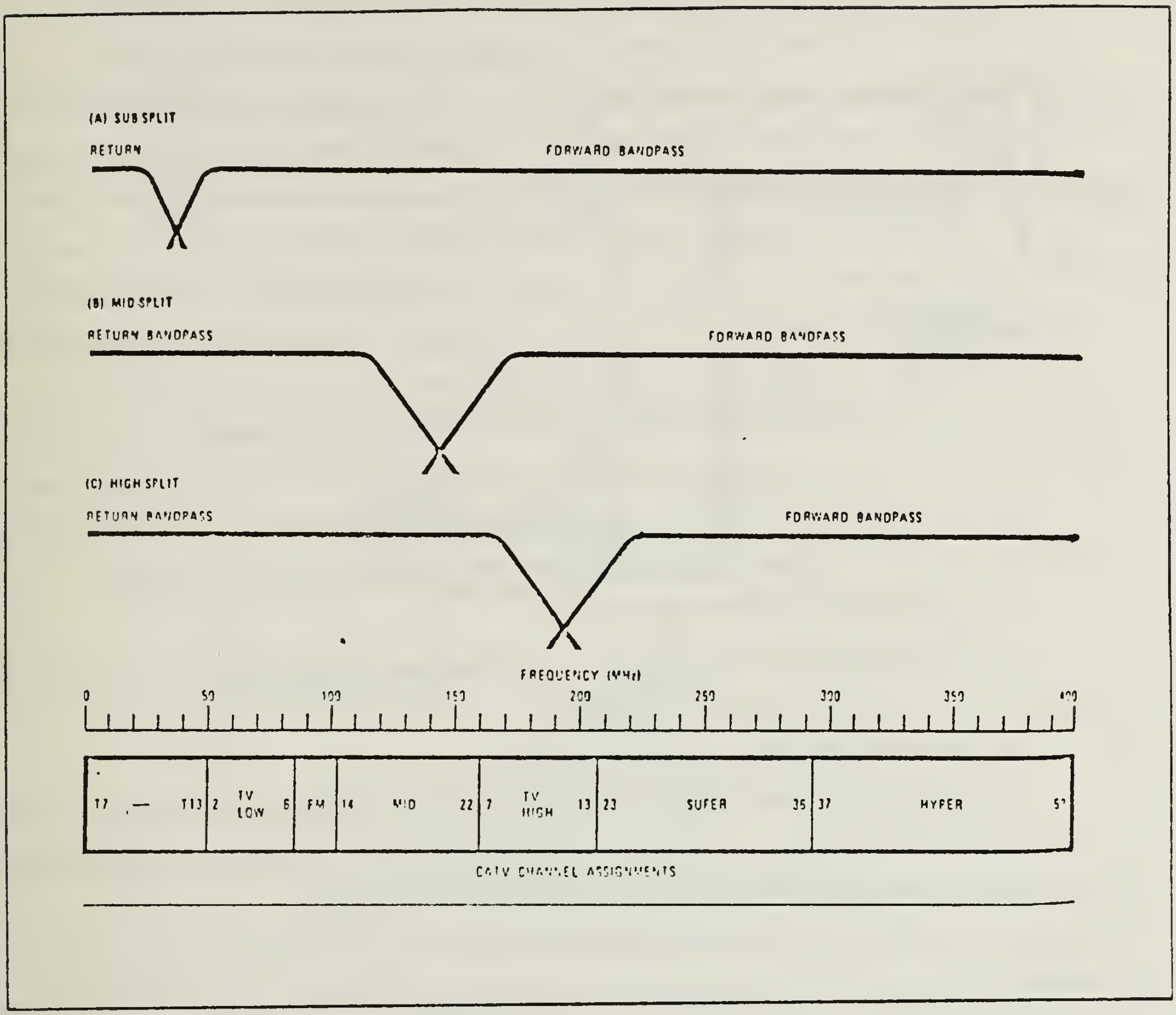


Figure 13. Frequency Allocation of the Three Split Format

installed in an existing facility. Single cable networks can be representing as a branching tree, which simplifies network design and also facilities network maintenance. It is easy to trace such a topology. Dual cable networks become a problem, since the loop must be maintained throughout the network.

We compare the three split formats and we select the mid-split format using single cable broadband system.

The components of the single cable broadband systems are cable (75 ohm coaxial cable) with 75 ohm terminator for all end-points, amplifiers, directional couplers, and controllers.

Cables used in broadband LANs are of three types: trunk, distribution, and drop cable [Ref. 3: p.83] and trunk cables for larger systems. Distribution cables are used for shorter distances. Drop cables are used to connect stations to the LAN. For single cable systems, amplifiers must be bidirectional, passing and amplifying lower frequencies in one direction and higher frequencies in the other.

Directional couplers or taps divide on input into two outputs and combine two inputs into one output. Splitters are used to branch the cable. The broadband tap is a passive directional coupler that provides a mechanical interface between the trunk and the drop cable. The maximum length between the tap and the modem is 50m.

In the military environment, network redundancy is desirable, since it provides a back up to crucial network services in case the primary network is damaged. In a mid-split network, two cables are installed side by side, providing the redundant communication path. Figure 14 shows the network redundancy [Ref. 13: p.122].

3. Layout of the system

Using the basic components of a broadband cable system, the layout of the military LAN can be drawn as in Figure 15.

4. Channel Allocation

A mid-split cable requires a headend device to translate the inbound frequency to the outbound frequency. The IEEE 802 local network standard specifies a single cable using a mid-split configuration. It refers to the frequency spectrum from 5 to 300 Mhz, with 5 to 108 Mhz reserved for the inbound frequencies, and 162 to 300 Mhz reserved for the outbound frequencies. The frequencies for 108 to 162 Mhz are reserved as a guardband to prevent interference between the inbound and outbound frequencies. Figure 16 shows the typical band allocation scheme [Ref. 14: p.132].

D. BROADBAND PERSONAL COMPUTER LANS

This section consists of hardware, protocols, bridge/gateways. We examined the broadband technology in the previous sections.

1. Hardware

The hardware for attachment of PC's to LANs typically consists of an adaptor card which is mounted internally to the PC chassis. It provides a high-speed interface to the PC's internal bus. For broadband systems, the LAN interface must include a modem. These components may be packaged in various combinations.

In addition to a network interface for each user device, a broadband system requires a cable system including a headend as we stated in the previous sections.

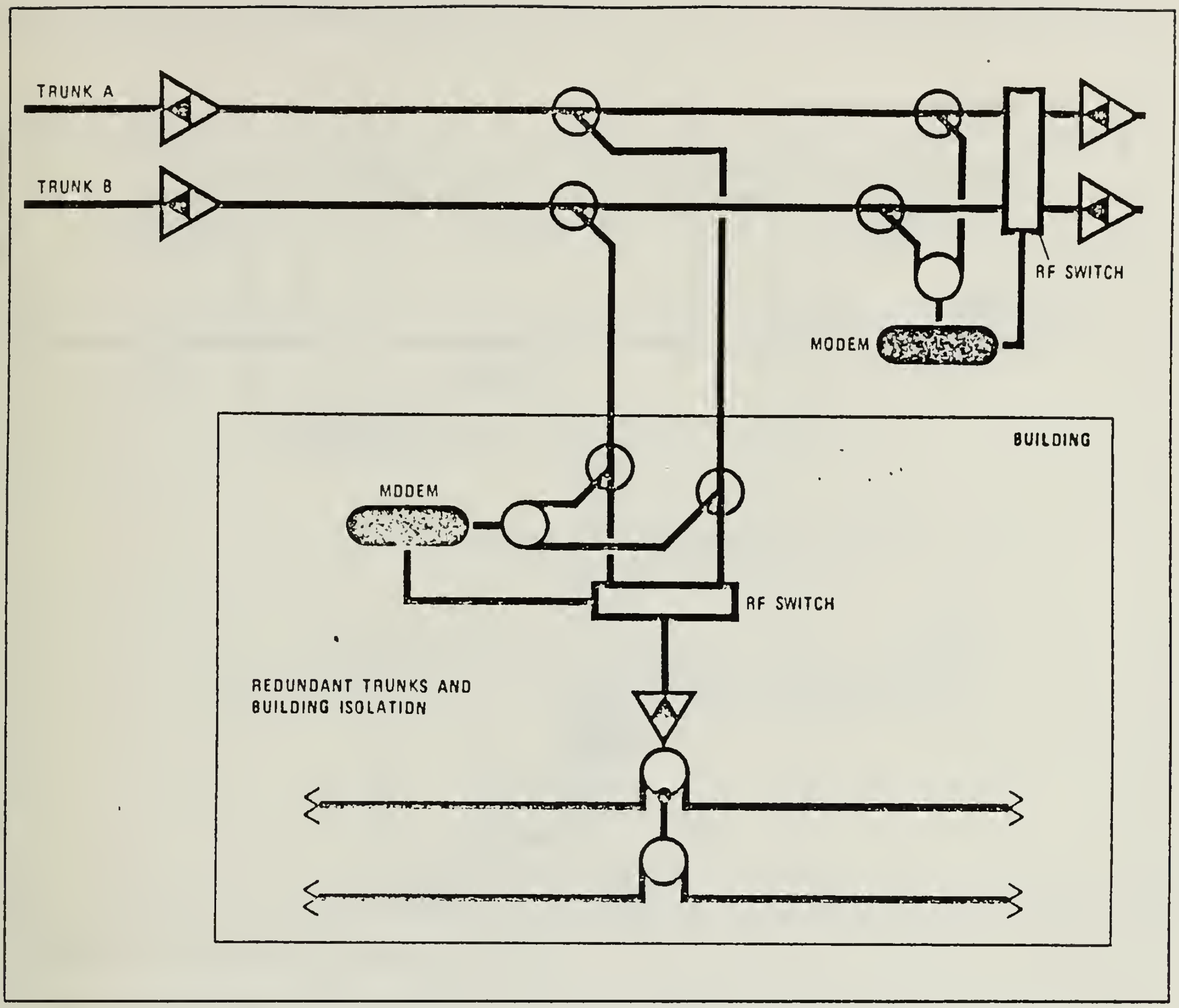


Figure 14. The Network Redundancy

Normally the cable is a standard commercial CATV system supporting multiple services. Headend equipment is available from several vendors, typically in increments of 6 Mhz channel slots. If a computer in the IBM PC Netis located more than 200 feet from the headend, the network must use base expander.

2. Software and Protocols

To provide full communication capabilities, all layers of the ISO protocol hierarchy should be provided. The physical level includes a modem in broadband systems, often supported along with the link level by a specialized controller located in the adaptor. Network, transport, and session level functions can be performed in the adaptor, providing a general purpose communication service to the PC itself.

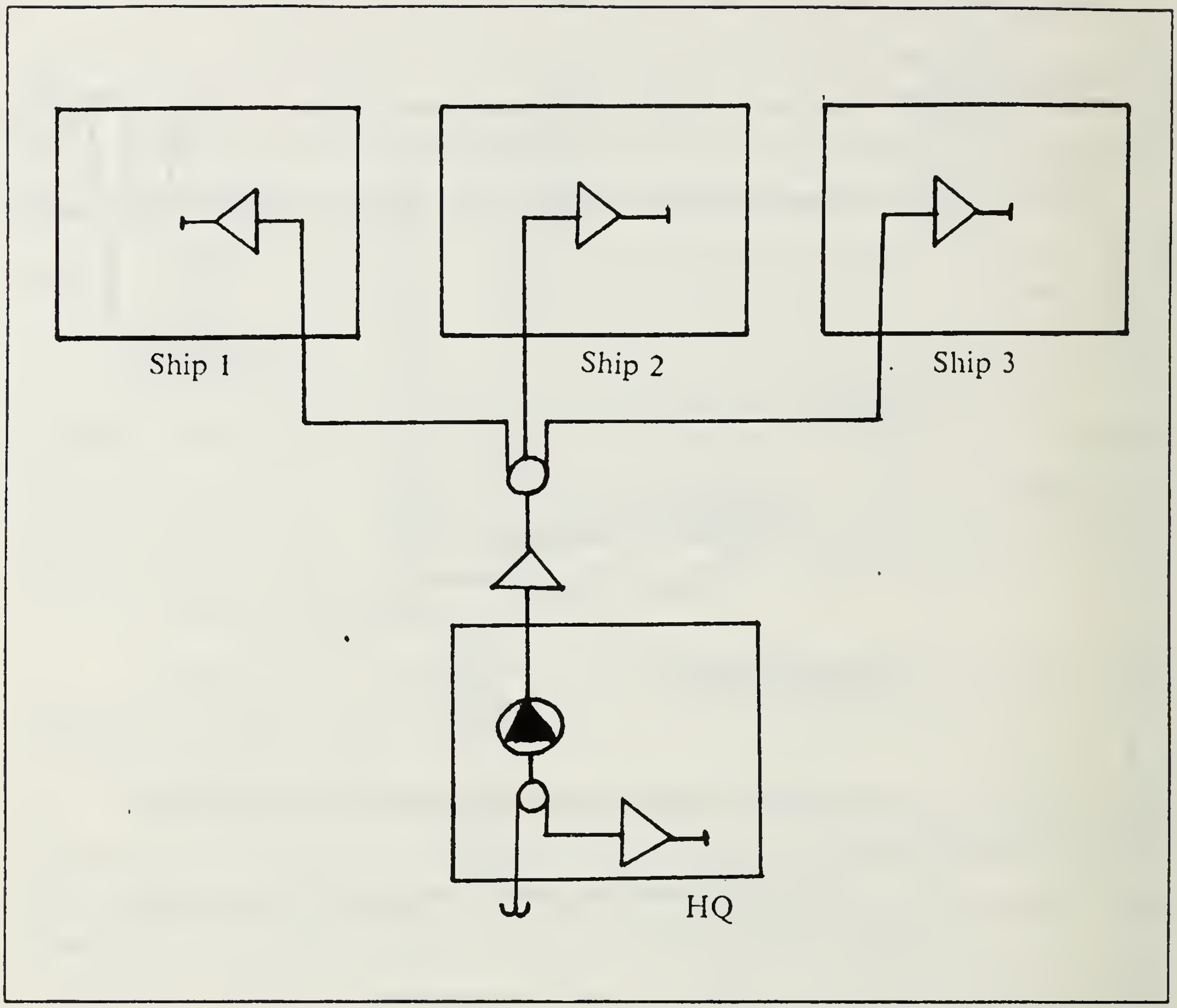


Figure 15. Layout of the System

3. Bridges

We want LANs on ships and between ships and HQ, so we need to connect the LANs by bridges. In broadband systems, at the physical level, the RF technology of cable splitters, combiners, taps, amplifiers to remote subheadends are used to provide channels over a wide area. Several different frequency channels may be used globally to support even more nodes, with the channels connected by bridges.

Separate cable segments, each with its own headend can be joined by bridges, allowing reuse of the same frequency channel on each segment.

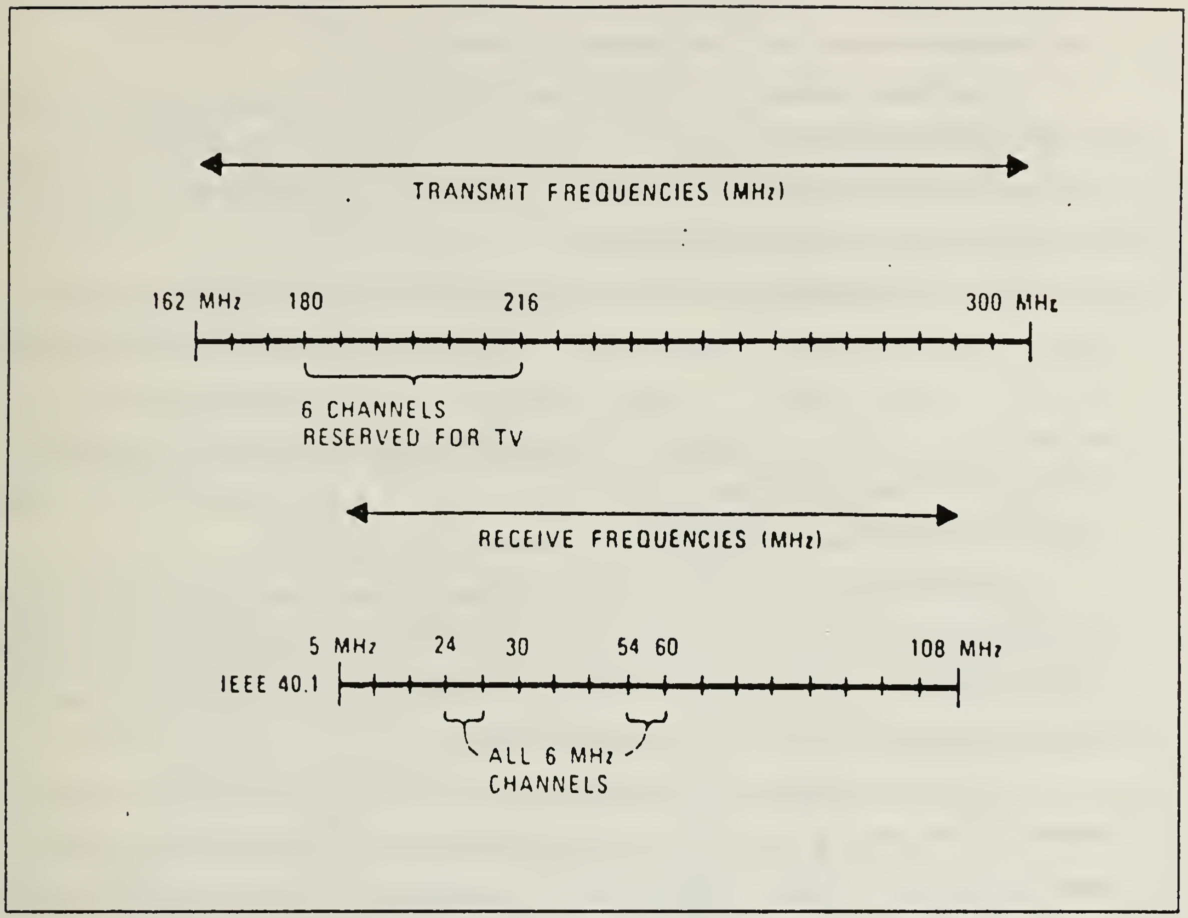

TRANSMIT FREQUENCIES (MHz)
162 MHz
180
216
300 MHz
6 CHANNELS RESERVED FOR TV
RECEIVE FREQUENCIES (MHz)
5 MHz
24
30
54
60
108 MHz
IEEE 40.1
ALL 6 MHz CHANNELS

Figure 16. IEEE 40.1 Band Allocation

4. Selecting The Configuration

There are two basic types of devices: servers and non-servers. It is best to configure all non-server PCs alike. We configure all non-servers as messengers. This will provide the most desirable features.

Under this mode of operation the PCs can perform functions such as using a server's disk, directory or printer; sending and receiving messages; saving messages received from other computers; using another name to receive messages; transferring messages to another computer; and using the network request key to switch from local application processing to the network program.

5. Selecting the Printer

Printers are essential when network and other data must be recorded on hard copy. There are five types of printers which are commonly used. These are: daisywheels, dot matrix, thermal transfer, color ink jet, and lasers. What are the advantages and disadvantages of each type? The answers are detailed below.

The major advantage of the daisywhell printer is its high reliability and print quality. Daisywheel printers operate at 20-80 cps (characters per second). The major disadvantage of the daisy wheel is its slow speed and its limitation to simple graphics. Word processing is one of its applications.

A major advantage of dot matrix printers is high speed, ranging from 60 to 400 cps in draft-quality mode. These printers are generally inexpensive. Another advantage of the dot matrix printer is its graphics capability. With the relatively new double-pass capability, dot matrix printers produce near letter-quality characters. The major disadvantage of the dot matrix printer still centers on print quality. Applications of these printers are spreadsheet, numerical data and graphics capability.

The advantages of thermal transfer printers include speed (300 cps), high speed (300 cps), quiet operation, and high print quality. One disadvantage of thermal printers is their high cost. Applications of these printers are document processing, integrated text and graphics, bolding, and margin justification.

Advantage of the color ink jet printer is its ability to mix colors. They can merge text with color graphics. The main disadvantage of the color ink jet printer is its speed: a fairly slow 20 cps. Applications for these printers include color graphics; complicated computer-aided design drawings, providing rapid visual discrimination; medical reports and graphics.

Laser printers offer a wide range of speeds, from 8 to 120 pages per minute. Text and graphics data are transmitted to the printer, with an entire page formatted before printing begins. They produce letter-quality printed output. The key factor a potential user of a laser printer should determine is the recommended average monthly page volume. The manufacturer designs its printer to handle a particular volume. Reliability depends on volume. The disadvantage of the laser printer is its high price. Applications for these printers include high-volume document production; graphics, logos, signatures, data and word processing, and engineering drawings [Ref. 15: p.110].

Compatibility and reliability is an important factor when choosing an appropriate printer. Price versus performance is the another key to determining the best use of a printer. We compared the types of printers, and we selected quality dot matrix printers.

6. Space Allocation

We need a plan for estimating fixed disk space requirements. The plan should give us the probable normal size expected for the various directories. A possible space budget is illustrated in Table 7 [Ref. 10: p.146]. The leftmost column of Table 7 shows the space that a directory is certain to consume for steady use. The next column, headed min, indicates the temporary space the user almost certainly needs in addition to the steady use. The rightmost column, headed "max", indicates the amount of temporary space the user may require during peak use.

Table 7. OUTLINE FOR A FIXED-DISK SPACE

Directory	Steady size (thousands of bytes)	Variable (min-max)
Network directory (server portion)	320	0 - 0
Spool files awaiting printer	0	100 - 8 000
Batch directory (server)	3	0 - 0
Apps directory Batch (for network)	3	-
Network (user portion)	320	-
DOS	350	0 - 0
Text	124	-
Application 1 (word perfect)	1 300	0 - 0
Application 2 (data perfect)	1 000	0 - 0
Application 3 (plan perfect)	1 500	0 - 0
User 1	1 000	1 000 - 2 000
User 2	1 000	1 000 - 2 000
User 3	1 000	1 000 - 2 000
User 4	1 000	1 000 - 2 000
Totals	9 220	4 500 - 16 000

E. CHOOSING A LOCAL AREA NETWORK

In the previous sections, we examined LAN design issues. Based on the specifications of the requirements of the Turkish Naval Base, LAN access method, transmission media, topology, transmission methods were selected.

- Coaxial cable
- Broadband

- CSMA/CD
- Bit error rate 10^{-9}
- 4 servers AT - 40 Mbyte hard disk, 1.2 Mbyte floppy drive, 360 K floppy drive, 1 Mbyte main memory.
- 16 users AT (80286) - two 360 K disk drives, 1 Mbyte main memory (expandable to accommodate O/S2 requirements).
- 4 dot matrix printer.

V. CONCLUSIONS AND RECOMMENDATIONS

The purpose of this thesis was to provide the key elements and guidelines for designing a LAN in the ship and between ships and HQ. In the first part of this thesis, overall system was reviewed, user requirements were identified and analyzed and then, several LAN requirements were identified. In the second part of this thesis, major design issues were examined. The issues include topology, transmission medium, transmission techniques, access methods, standards, and PC LAN configurations.

In the last part of this thesis, major design issues were compared with requirements and selection trees were used to select LAN components. The LAN was selected and recommended.

It is expected that this study can serve as a guideline for constructing the LAN to connect system elements. Packet radio could be used for communication between ships at sea and between ships and HQ. This is a subject for future research.

APPENDIX A. NETWORK TRAFFIC CALCULATIONS

The statistical characteristics of each application was shown in Table 1. In ~~the~~ Table 1, "duty factor" describes average data rate of each application as a percentage of peak data rate. It means that a period of data transmission is not always operating at peak data rate. The period of data transmission depends on the applications. Thus, to calculate traffic requirements for the system, we have to multiply peak data rate by duty factor. The result of the multiplications are shown in Table 8.

Assumptions have been made about the nature of the traffic which would be generated in typical departmental configurations. The percentage usage rate of each application by a work station is estimated and shown in column 5. Multiplication of average data rate with usage rate of each application gives the data rate of the application for per user per second. Summation of column 6 gives the required data rate of each user.

Table 8. NETWORK TRAFFIC

APPLICATIONS	Peak data rate (kbps)	Duty fac. (%)	Average data rate (kbps)	Usage rate (%)	Data rate (kbps)
Word processor	9.6	5	.48	35	.168
Data base	9.6	10	.96	15	.144
Spreadsheet	9.6	10	.96	15	.144
Line printer	19.2	70	13.44	5	.672
File/server transfer	100	30	30	5	1.5
Mail server	100	50	50	20	10
Graphics	256	10	25.6	5	1.28
Data rate for per user per second					13.908

With 20 users, the total system load is 278.16 kbps. This figures represents a maximum load assuming that all users are active simultaneously. Such volume is unlikely to happen; however, it does provide a potential load figure for the source utilization profile. Because of the popularity of the Ethernet CSMA/CD access protocol, to estimate overhead data, we can take into account the Ethernet frame format which is shown in Figure 17 [Ref. 16: p.91].

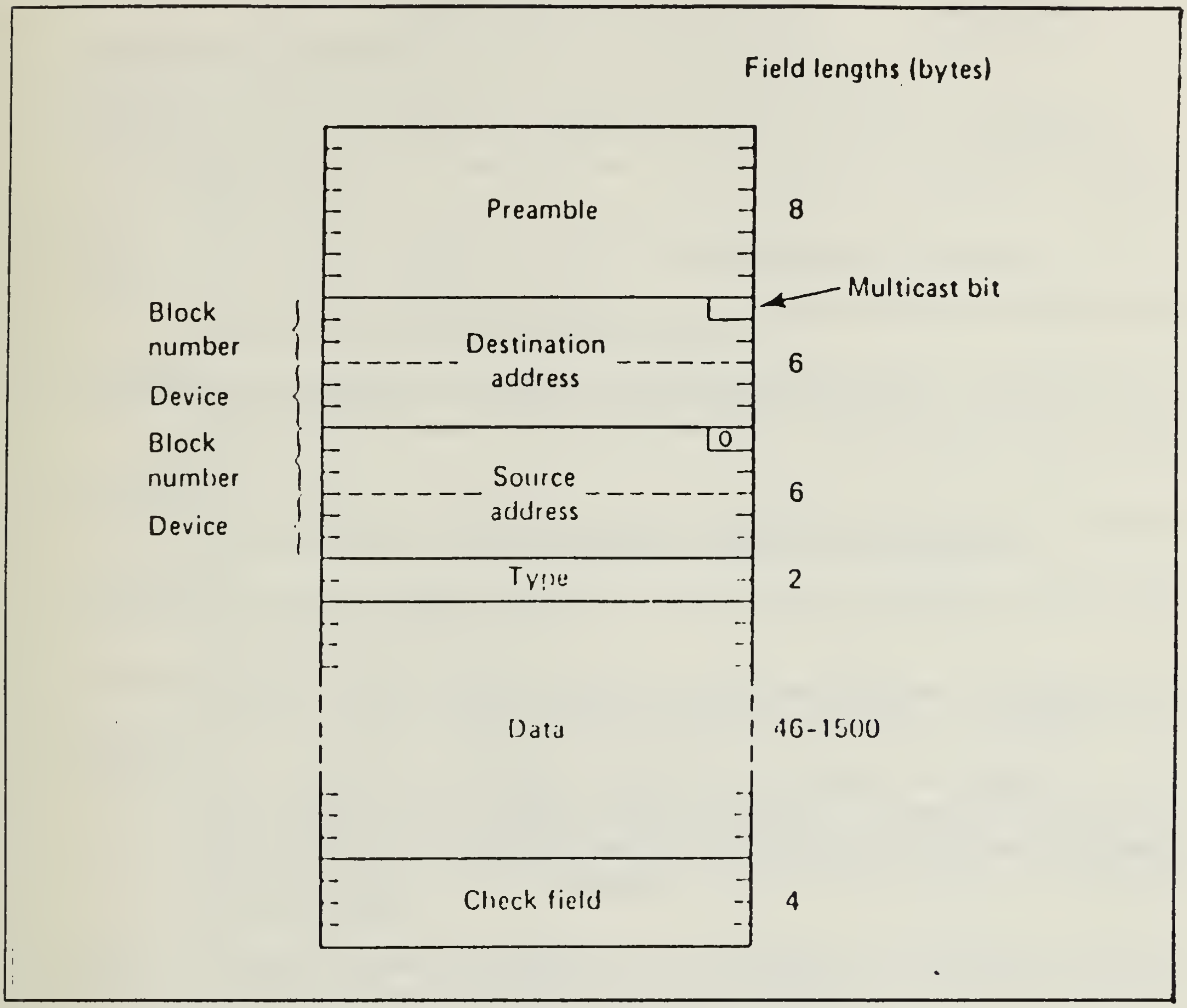


Figure 17. Ethernet Frame Format

The Ethernet frame format has 26 control bytes and the 802 standard recommends that the length of the data field would be between 46 to 1500 bytes [Ref.8: p.385]. With 46 bytes data field overhead data is 36.11 %. With 1500 bytes data field overhead data is 1.7 %. The maximum packet size is based on efficiency and collision avoidance. 512 bytes packet length is optimum. [Ref. 17: p.245]. For 512 byte packet length overhead data is 5 %. Thus,

Useful data = Total data - Overhead data - Data transmitted in error

Useful data transfer can be computed by the formula. In the formula error rates are ignored since typical error rates are 1 bit in a billion for LANs. The useful data is 264.25 kbps.

APPENDIX B. GLOSSARY

BASEBAND: Transmission of signals without modulation.

BRIDGE: A device that links two homogeneous packet-broadcast local networks.

BROADBAND: The use of coaxial cable for providing data transfer by means of analog signals.

BUS: One or more conductors used for transmitting signals or power.

CATV: Community Antenna Television. CATV cable is used for broadband local networks, and broadcast TV distribution.

CIRCUIT SWITCHING: A method of communicating in which a dedicated path is established between two devices through one or more intermediate switching nodes.

COLLISION: A condition in which two packets are being transmitted ove r a medium at the same time. Their interference makes both unintelligible.

CONTENTION: The condition when two or more station attempt to use the same channel at the same time.

CSMA/CD: Carrier Sense Multiple Access with Collision Detection. A refinement of CSMA in which a station ceases transmission if it detects a collision.

DATAGRAM: In packet switching, a self-contained packet, independent of other packets, that does not require acknowledgment, and that carries information sufficient for routing from the originating data terminal equipment without relying on erlier exchanges between the data terminal equipments and the network.

FDMA: Frequency-division multiple access. A technique for allocating capacity on a sattellite channel using fixed-assignment FDM.

GATEWAY: A device that connects two systems, especially if the systems use different protocols.

LAN: Local Area Network. A general-purpose local network that can serve a variety of devices. Typically used for terminals, microcomputers, and minicomputers.

PROTOCOL: A set of rules that govern the opreation of functional units to achieve communication.

REPEATER: A device that receives data on one communication ring and transmits it, bit by bit, on other link as fast as it is received, without buffering.

RING: A local network topology in which stations are attached to repeaters connected in a closed loop. Data are transmitted in one direction around the ring, and can be read by all attached satations.

TOKEN: A medium access control technique for bus/tree. Station from a logical ring, around which a token is passed. A station receiving token may transmit data, and then must pass the token on to the next station in the ring.

TOKEN RING: A medium access control technique for rings. A token circulates around the ring. A station may transmit by seizing the token, inserting a packet onto the ring, and then retransmitting the token.

TOPOLOGY: The structure, consisting of paths and switches, that provides the communications interconnection among nodes of a network.

TRANSMISSION MEDIUM: The physical path between transmitters and receivers in a communication system.

TREE: A local network topology in which stations are attached to a shared transmission medium.

UNBALANCED TRANSMISSION: A transmission mode in which signals are transmitted on a single conductor. Transmitter and receiver share a common ground.

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